Science Teaching in Schools

R.C. Das

In today's space age, science has permeated through human life in such a way that it has now become everyman's everyday concern. Since it affects the common people, the learning of science must reach the masses. To equip the new generation with scientific knowledge, science must be taught by teachers all of whom may not be experts. To make large-scale teaching of science effective by average teachers, it is imperative that they be trained to do so under existing situations. This revised and enlarged edition of *Science Teaching in Schools* brings into discussion important issues of classroom teaching of science at the secondary stage, and can serve as a textbook for the B.Ed. course and as a handbook for science teachers.

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To my father
who is no more

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Foreword

In our contemporary civilisation and culture, science has become a part and parcel of our life. In the advanced countries science has entered the very fabric of life and even in the less advanced countries its impact on life is felt in an ever increasing manner. Science today dominates such a wide area of human activity that it is no longer the concern of a select group of people in a society but has become a part of the everyday job of almost everybody everywhere.

Such a situation obviously demands everyman's acquaintance, with science, both as a product as well as a process. A man without contact with science and its manifestations will be a complete misfit in modern society. If we conceive education as a process for preparation of a socially efficient citizen, it is imperative that each individual of the society acquires knowledge of science as well as a scientific attitude of mind as a consequent discipline. It is, therefore, no longer the problem of teaching science to a select group of students by specialised expertise in science but of teaching science to each and every student by teachers all of whom may not be experts. The need of the day is to achieve large-scale teaching of science through average teachers. This obviously warrants training of teachers for teaching science effectively to large numbers.

Teachers, it is said, are born; but even such a teacher is born with an aptitude rather than with a technique. So even born teachers may need some orientation. Besides, at a time when we need thousands of teachers, a few born teachers are not enough. We have to create them through deliberate effort.

In the present book Dr R.C. Das, Principal, State Institute of Education, Assam with his long and varied experiences in the

line, both in India and abroad, has brought into discussion the important issues pertaining to classroom teaching of science at secondary stage. It is expected that the book will help the teachers under training to gain some insight into the problems of teaching science and to handle their job with confidence.

S.C. RAJKHOWA
Retd. Vice-Chancellor
Gauhati University

Introduction

I HAVE GREAT pleasure in introducing this book *Science Teaching in Schools* to the readers written by Dr R.C. Das, now Inspector of Colleges in this University. In fact, such a book on teaching of science to our school children was a long-felt need particularly in this part of the country. Dr Das has fulfilled this urgent need. I sincerely hope this book will significantly help the science teachers of the secondary schools in improving their science teaching to the students.

In this present scientific age when man is galloping to the space age, discovering the secrets of nature, when science has been providing material convenience and comforts to man and when the creations of science have been doing the job of men, thinking on behalf and even taking decisions on behalf of men, it is absolutely necessary that each and every individual should acquire a minimum general knowledge of science for his own survival as an individual and to make himself useful to the present-day society. Simultaneously, the value aspects of science and its creations need also be brought home to each and every individual so that the apprehension which is often expressed in many quarters that man is being mastered by science instead of his mastering it, is allayed. In this book, Dr Das has laid special emphasis on the socio-cultural aspects of science education and on the mental attitude and outlook this should generate in our new generations.

I believe the teachers of science, after going through this book, will be able to appreciate this point of view and will develop an approach for imbibing a correct attitude to science in the student community. In this book the author, with his wide experience in the area of science education, both in India and

the United Kingdom has, dealt with various aspects of science education beginning from the history of its development to the planning of classroom lessons and evaluation. This will immensely benefit science teachers teaching science in schools and will be of significant help to science teachers undergoing B.T./B.Ed. course.

I congratulate Dr Das for this valuable work so essential at this present juncture.

S.D. Gogoi
Vice-Chancellor
Dibrugarh University

Preface to the revised edition

THE BOOK in the original form was published in 1965 and all the copies were sold out long back. But before the book could be revised and updated, the ever-increasing influence of science and technology brought further and faster changes not only to the material environment of the world but also to the mental outlook, attitudes and the ideas of its inhabitants. Such changes in the modern scientific world obviously had their impact on the educational thought and process in society. It thus became necessary to incorporate in the book all these changes in ideas and attitudes. While doing so, the original book had to be totally revised, enlarged and updated.

In this age of space technology, science has permeated through the human life in such a way that, it has now become everyman's everyday concern. It has reached the common people and as such, learning of science must now reach the masses. The new generation must be equipped with the scientific knowledge and attitudes to grow and live in the modern world as efficient citizens. Science must now be taught extensively by teachers all of whom may not be experts. Further, science will have to be taught under the existing conditions of our schools. But we must be careful that whatever and however science is taught, it must be taught in its proper perspective.

To make large-scale teaching of science effective by averge teachers, it is imperative that these teachers be properly trained to teach science scccessfully under the existing situations. We can ill-afford to wait long to prepare teachers of science in large numbers through training. While undergoing such training, the science teachers need relevant reading materials to enable them to successfully complete the course and also help them in

their professional growth. It is for this purpose that the book has been revised and updated and new chapters added to bring it out in the present shape.

It is hoped that this revised and enlarged edition will meet the current needs of the science teachers and will help them improve classroom teaching of the subject.

I offer my sincere gratitude to: Sri Suresh Chandra Rajkhowa, former Vice-Chancellor of Gauhati University, for writing the 'Foreword' to the book and Dr Sailadhar Gogoi, Vice-Chancellor of Dibrugarh University, for being so kind as to 'Introduce' the book to the readers. I am profoundly indebted for their generosity and encouragement.

I also record my appreciation, at the same time conveying my love and affection, to Sriman Bhaskar Jyoti Das, my son, for the unflinching loyalty displayed by him and helping me in collecting and organising the materials.

Dibrugarh

R.C. DAS

Preface to the first edition

THE MODERN world is a scientific world and today science is everybody's concern. At this stage we cannot think of a world without science. In Joseph Gallant's words: "The most conspicuous aspect of our civilisation today is the pervasive and ramifying impact of science in every department of life, from household management to warfare." Such a remarkably amazing achievement of science as in the present century, did never occur before in the long history of human civilisation. But there was a time when science was the refuge of the destitute; it has a long history of struggle for recognition. We can best realise it when we remember the life of Galilio Galilie, the father of modern science. In 1610, he sadly wrote to his friend, the great German astronomer Kepler: "My dear Kepler, what would you say of the learned here who, replete with the pertinacity of the asp, have steadfastly refused to cast a glance through the telescope? Shall we laugh or shall we cry?" Even in 1860, Herbert Spencer wrote, "Science forms scarcely an appreciable element in our so-called civilisation." If they were alive today, they could not have believed that such a tremendous change in human outlook could occur.

In view of the dominating role of science in the modern world, it has been imperative for any nation of the world to promote science education in their country. Rapid industrialisation and technological developments are the special features of the world today. The ever-increasing pace of science has created a wide gap between the developed and the underdeveloped countries. It has, therefore, necessitated the under developed countries to take more vigorous steps towards scientific and industrial developments in order to bridge the gap. We cannot

expect improved science education in the higher institutions of science and technology unless we succeed in providing a sound science education in schools. Moreover, every citizen of the modern world needs to know sufficient quantum of everyday science during school education.

Improved science teaching in schools depends upon teachers properly trained in the methods and techniques of teaching science. One of the main bottlenecks in improved science education in our schools is the lack of trained teachers. In the developed countries, books, pamphlets and magazines relating to the methods and techniques of teaching science are available in plenty. But, in India, such materials are deplorably limited. This humble effort has been made to provide to the secondary school science teachers a ready handbook to help them improve their classroom teaching as well as to serve as a text during the period of training.

More emphasis has been given on the teaching of general science to every student and under the existing conditions in the schools. Whatever practical suggestions have been offered in this book, are based on my experience gained through working with the science teachers of the secondary schools of Assam. Further, my participation in a large number of seminars, workshops and conferences on the teaching of science, both in India and the United Kingdom, has helped me to develop an insight into the problems of science teaching in the schools. I hope the book will serve as a textbook for the B.T./B. Ed. science teacher trainees and also as a handbook for all teachers of general science in the secondary schools.

R.C. Das

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Science as a Subject in Secondary Schools

Science does not simply sit down and pray for things to happen, but seeks to find out why things happen. It experiments and tries again and again and sometimes fails and sometimes succeeds—and so bit by bit it adds to human knowledge. This modern world of ours is very different from the ancient world or the middle ages. This great difference is largely due to science.

My preferences are all for science. The world is a narrower ;place now and there is little to discover in it. So it seems. But that is not so, for science has opened up tremendous new vistas which wait to be explored, and of adventure there is no lack, especially in India today.

—Jawaharlal Nehru

A. Science and the mordern world

The modern civilisation is a scientific civilisation. This is an age where the modern society is completely drawn into the scientific environment; and science has become an integral part of our life and living. Now, we cannot think of a world without science. The wonderful achievements of science have glorified the modern world. In the words of A.N. Whitehead, "the great conquerors from Alexander to Caesar and from Caesar to Napoleon, influenced profoundly the life of the subsequent generations. But the total effect of this shrinks to insignificance if compared to the entire transformation of human habits and human mentality produced by, the long line of men of thought from Hales to the present day."

A citizen of a modern world sees the countless manifestations of science all around him. There is no aspect of man's life today which has not been influenced by science one way or the other. This is because we are living in an age of scientific culture. Science has shrunk the world and totally changed the human outlook. In fact, science now has an all-pervading influence on every sphere of human activity. Further, modern science is no longer confined to the surface of this globe; its sphere of achievements reaches beyond the earth.

In recent times, there has been rapid addition of knowledge to the world of science. Great advancements of science and technology and the use of these scientific achievements in promoting the well-being of mankind through their application in the field of industry, communication, transport, engineering, agriculture, medicine has made science more important than ever before. Science has, in fact, radically transformed the material environment of the citizens of the modern world. In addition to the immense and far-reaching material benefits of science, as the Indian Education Commission puts it "... but even more profound is its contribution to culture. Science is liberating and enriching the mind and enlarging the human spirit. Its fundamental characteristic has turned out to be the possibility of unlimited growth. Every advance in science deepens our understanding of nature but it also heightens the sense of ignorance. Nature is inexhaustibly knowable. Nothing comparable to the scientific revolution in its impact on man's development and outlook has happened since the neolithic times."

B. Science in school curriculum

We have to live in a scientific civilisation whether we like it or not. Science is no longer confined to a few seriously devoted persons. Since living in the present world invariably warrants, to variable degrees, knowledge of scientific facts and laws, science has now become everyday science for everybody. Teaching of everyday science for everybody has become an unavoidable part of general education. Nobody questions its inclusion as a subject in the school curriculum. It is included in a school's curriculum for the same reasons as any other subject. but in

addition science inculcates certain special values peculiar to it and which no other subject can provide. It is a part of liberal education. But besides satisfying the usual needs for its inclusion as a subject in the curriculum—such as intellectual, cultural, moral, aesthetic, utilitarian as well as vocational values—science learning provides training in scientific method and also helps to develop a scientific attitude of mind in the learner. The qualities imbibed by the learner through learning science are valuable for a citizen living in the society. Science is now a compulsory subject in every system of school education right from the elementary stage.

In the past science had to struggle long and hard for its rightful place in the school curriculum. There was a time when science was considered an inferior subject to study and the meritorious students were supposed to study classics and mathematical subjects. New ideas or inventions in science were not immediately accepted in the society and were looked upon with suspicion. Any new idea that went against the prevailing beliefs and codes of the time was condemned.

Even Galilio Galilei, after the invention of the telescope had to write to his friend, the German astronomer Kepler, "My dear Kepler, what would you say of the learned here, who replete with the pertinacity of the asp, have steadfastly refused to cast a glance through the telescope? Shall we laugh or shall we cry?" There was a time when many scientists refrained from making their new scientific ideas public for fear of social repercussion. Experimentation or practical work in science was also considered an inferior job.

The real significance of science was never realised till the beginning of the nineteenth century and that is why we see that science had no place in the school curriculum during the earlier days. The pursuit of science was either a hobby of the people with means and leisure or the solitary efforts of someone with scientific talents. Even up to the middle of the nineteenth century, when sporadic efforts were made to introduce the study of natural science at the universities, it did not attract many students. Science was never a course of regular study either in universities or in schools. Since the beginning of the eighteenth century, however, a number of societies were formed in Europe and

individual efforts were made for the popularisation of science. Such efforts have a long history beginning with Roger Becon of the thirteenth century to Francis Bacon, Gilbert, Herbert Spencer, Tyndall, Huxley, Faraday, Armstrong and others· who made efforts to popularise science. They pointed out its necessity for an all-round education of man. Benjamin Franklin did the same in America. Their efforts resulted in creating favourable opinions in society towards securing the rightful place for science as a subject to be studied. Herber Spencer (1820-1903) not only advocated the teaching of science but also proved science to be the most worthy subject of study from the utilitarian point of view in his book *What Knowledge is of most Worth.* On the other hand, T.H. Huxley (1825-1895) wanted to show in his essays that science was beautiful. He pleaded for the inclusion of science in general education emphasising that learning of science can develop various favourable outlooks in the learner.

It needed great effort and hundreds of years to popularise science even in its homeland, that is, Western Europe where modern science originated. The proceedings of the Royal Institute, London, record that the scientist, Michael Faraday, urged thus in 1858: "As a branch of learning, men are beginning to recognise the right of science to its own particular place; but now the fitness of university degrees in science is under consideration, and many are taking a high view of it, as distinguished from literature, and think that it may well be studied for its own sake i.e., a proper exercise of human intelligence, able to bring into action and development all powers of the mind." In India, the teaching of science followed the developments in England. But whatever development took place in India in the teaching of science was extremely slow. The teaching of science in schools in India was conspicuously deplorable till after 1953 when the Secondary Education Commission, popularly known as the Mudaliar Commission, recommended teaching of general science as a compulsory subject at the secondary school stage

C. Values of science as a subject

Galilio Galilei (1564-1642) once said that in questions of science "the authority of a thousand is not worth the humble

reasoning of a single individual." Though he referred to the faculty of theoretical reasoning, he was the first experimental scientist. While learning science, the learner develops certain faculties through reasoning and experimentation which no other subject can provide. Science, as a teaching subject, possesses the various values as any other subject for which it is included in the curriculum as a teaching subject such as intellectual values, utilitarian values, cultural values, moral values, and aesthetic values. But in addition, the study of science inculcates certain other disciplinary values peculiar to it which cannot be provided through other subjects.

Considering the subject from the intellectual point of view, science is the most inexhaustible storehouse of knowledge. It is opening new horizons of knowledge everyday and is continuously adding to the cultural heritage of mankind the ever-increasing new knowledge, new explorations, and new ideas. Along with acquisitic n of expanding knowledge, it makes man aware of the vastness of the unknowable in the universe. The fundamental characteristic of science is its possibility of unlimited growth. Since Nature is an inexhaustible source of knowledge, science as a subject, offers the widest range of knowledge to the learners. As such there is infinite scope for broadening one's horizon of knowledge. The world-wide researches and experimentations in the field of science and the advancements in the area are adding everyday to the already accumulated enormity of scientific knowledge. Acquiring knowledge for the sake of knowledge itself is one of the characteristics of civilisation. In fact, science is both the foundation as well as structure of our modern civilisation. It has exposed to mankind infinite avenues of knowledge in nature, living and non-living—the world we perceive and also the world beyond human perception thereby makes us conscious of the unknown to be explored. These are the special features of a dynamic and ever-growing civilisation. The expanding universe of knowledge, material to etherial, does satisfy our intellectual query. Science developes insights into the mysteries of creation and existence which have always attracted the attention of man since the dawn of civilisation.

Science, besides satisfying the intellectual curiosity of man and providing materials and media for intellectual exercise, has

disciplinary effect on the minds of men. We may call it the disciplinary values of science. Since science covers the widest range of knowledge, the learner wonders at the intricacies and mysteries of the universe, the known and the unknown. These tend to create a broader outlook in the mind of the learner.

Further, science is universal in character; it has no barrier of any kind. It is international in outlook. The scientific revolution began in Western Europe where modern science was born but its home is now the whole world. The fruits of scientific discoveries in one country are enjoyed by the people all over the world. Science is not concerned with caste, creed or colour nor recognises territorial barriers. Such a pattern inherent in science will definitely have an impact on the minds of the learners and is expected to help develop broadmindedness in them.

The study of science has several other disciplinary values. For instance, science is an interest-awakening subject; its pursuit demands persistent efforts, diligence and patience. Any experimentation in science requires keen observation, concentration of mind as well as accurate representation of facts. There is no place for prejudice or bias in science. Scientific pursuits warrant objective observation and impartial judgement. Engagement in any scientific activity, be it theoretical or experimental, therefore, presupposes intellectual honesty, perseverance, concentration of mind and broadmindedness. In science we do not conclude or predict anything on the basis of superstition, traditional belief or hearsay, unless the facts are based on proof. In science there is no place for sentiment or emotion save rationality. A scientific result to be acceptable must be valid for all cases.

In pursuing a scientific problem, one has to define the problem, plan the process, collect relevant data, formulate necessary hypothesis, repeat the processes if necessary, apply to specific cases before generalising. During the process, one has to be logical and objective at every step. Thus, scientific pursuits demand such qualities as minute observation, scientific attitude of mind, persistence, perseverance, concentration of mind, accuracy of measurement, patience: logical, objective and unprejudiced judgement; respect fc other's opinion, respect for truth, etc. These disciplinary qualities of mind, if cultivated through the teaching of science, may be carried over to manifest

in the general behaviour of the learner. This will prove useful for living as an efficient social individual in the society. No other subject provides for inculcation of so many disciplinary qualities of the mind of the learners.

It is hardly nécessary to elaborate the utilitarian or practical values of science. The present world is a world of science and technology. Every thing or every event happening around us demands some knowledge of simple scientific facts or principles. Without the elementary knowledge and information of science, we will be at a loss in the society. Science is now everyday-science for everybody; its knowledge must no longer be confined to the classes but must reach the masses.

The achievements and the benefits of science touch all sectors and all levels of the modern society. The modern man has applied science and technology for the well-being of mankind by inventing machines and by harnessing the resources of nature. The gifts of science have been profitably used for making life comfortable and raising the standard of living. But the use or abuse of the wonderful gifts of science depends on man and his mind. The recent advances in the field of science and technology and the wide application of the achievements of science in industry, agriculture, medicine, transport and communication as well as their uses in domestic life justify, more than ever, the utilitarian values of science.

Science has opened innumerable avenues for pursuing different vocations. A student of science can study engineering and technology, medicine, agriculture or any similar subject and make his career in that profession. In addition, scientific activities have given rise to many varieties of crafts and allied services. Science, therefore, gives opportunities for career-making and pursuing professions and vocations. In fact, if we refer to "preparation of the individual for the future" as one of the aims of education, then science, as a subject, is rightly serving this purpose. In this age of science and technology there is a demand for technical personnel. The maintenance and creation of new departments, new establishments need the services of engineers, scientists and technicians and there will always be need for research workers in new fields of science. Educationist Paul Fredman once said, "science is no longer the preserve

of a few completely—perhaps abnormally devoted men; it is becoming and increasingly will become, one of the major professions open to any young man of ablility, demanding no more in the way of special bent or devotion than medicine or law. But like those other professions, it too will continue to offer a life with characteristic flavour; it will have its own professional standards and its own typical type of thinking and will call forth its practitioners its own loyalties."

Science has made a tremendous impact on the cultural life of tne present day society which is a product of science. The thinking, feeling and actions of a modern man are practically guided by the effects of science. There is an involvement of .science, direct or indirect, in all works as well as leisure of a modern man. Our habits and attitudes have also been affected by science.

The study of science brings behavioural change in the learner and enriches his character and personality. Science gives opportunity for creative thinking and constructive imagination. Further, science is a subject where ideas can be experimented upon and verified. The learner develops the habits of searching for the truth. These qualities affect the pattern of behaviour of the learner. The significant aspect of science is that whatever the student learns has immediate application in the world around him. This is educationally very sound.

In society, there will always be problems to be solved. One of the very useful outcomes of learning science is the development of problem-solving skill. If properly cultivated through the teaching of science, the students can apply this skill to solve problems in his personal or social life.

One of the aims of modern education is to provide means for utilisation of leisure especially in the industrialised societies. There is no end to interesting pursuits in science, intellectual or otherwise. Scientific activities provide the best hobbies and pastimes for worthy utilisation of leisure.

At higher levels, arts and science are no different. There can be no good piece of art without application of science and on the other hand there is artistic or aesthetic element in all scientific activities. The great thinkers have always been stressing the unity of science and arts and that they originate from the same root. In the modern civilisation, scientific creations glorify arts

and aesthetics and science may be said to be the modern substitute for arts in the sense that it is the result of the same kind of creative thought and action which generated arts. Plato (427-347 B.C.) clarified this misunderstanding long before the evolution of modern science: "We have certain tendency, on the part of literary and scientific forms, to diverge and develop along different lines, with growing hostility, which suggest fundamental incompatibility . . . this divergence and one-sidedness needs to be overcome. The origin of both literature and science is the same." Arts and aesthetics are components of culture and civilisation. The creation of the universe is a great piece of art. There is aesthetics in the mysteries and harmonies of nature. Saunders, in his book *The Teaching of General Science in Tropical Secondary Schools* writes:

> There is an aesthetic side to the scientist's activities and to his contribution to human culture. On the lowest level he has the satisfaction of adding to the sum of human knowledge; on a higher level he enjoys the subtle pleasure of devising some hypothesis which fits a diversity of facts opening up new areas of knowledge. Appreciation of 'fitness of purpose', the suitability of an apparatus for the job for which it was designed, can give great inward satisfaction. There is a pleasing skill in avoiding or eliminating sources of errors and in particular the errors of human observation. Wonder is aroused by neatness with which some material quality or some living activity, can be sorted out from other qualities or activities for examination and demonstration. There is an elegance that runs through the logic and handiwork of the scientists. It is seen in the formulae of mathematicians, it is equally seen in the experiments and observations of great naturalists. The very simplicity of great generalisations of science stirs the imagination. With microscope and telescope the scientist opens up new worlds of wonder and beauty. A speck of living matter becomes a creature of incredible beauty, a snow flake more lovely than diamonds, a distant star becomes a universe. It is at this level that science shares equally with the arts; the privilege of contributing to the aesthetic development of the human race.

Culture, in addition to knowledge, includes all activities, thoughts, feelings, attitudes, patterns of individual or social life of men. The study of science gives opportunity for the development

of favourable traits of human character which become a positive contribution to the cultural life of the society. For instance, with science gaining ground and spreading its influence in the life of man, there has been a profusion of literature based on science. Science fiction being interesting it adds to the cultural heritage of man. Similarly, the literature on history and development of science is no less interesting. It is the study of the origin and development of civilisation itself and has developed into a separate branch of study which contributes to the cultural heritage.

The biographies of scientists incorporated in the science course develop a scientific attitude among the learners. The description of the scientists' pursuits, their tenacity and perseverance, are worth reading. Such a study brings out the scientists' attitude towards science and their hopes and frustrations on their way to discovery. Sometimes, even after their invention or discovery, it takes a long time for social acceptance. The facts about the sacrifices of the scientists for the benefit of mankind stir one's imagination. The lives of Galileo, James Watt, the Curies and others show how the scientists had to suffer to make an original discovery. The lives of the scientists can inspire the minds of the young learners. It is believed that the study of science and the life of the scientists engenders praiseworthy humility.

The study of the scientist's way of discovery is more interesting. It gives the learners an opportunity to grasp the essential steps of scientific method or procedure. For example, the story of the discovery of the Laws of Gravity by Sir Issac Newton or the story of the discovery of the cause of malaria, by Sir Ronald Ross, will help to make the meaning of science clear. It is useful to give the pupils, the idea how scientists sacrifice their personal comfort for the good of society. Broadmindedness and selfless service to mankind are characteristics of their lives.

Science learners can be provided the opportunity for literary expression by being asked to write the details of their observations, procedures and conclusions of scientific experiments they perform. They should be encouraged to write all observations precisely. For example, on completion of a project, an experiment or a field trip or observation of a scientific demonstration,

the students may be asked to write an essay describing all aspects of such an undertaking. Here, the student will have to be creative in his writing and will learn the use of right words to describe his experience which is a good exercise in composition and translation of thoughts and feelings into words.

In the study of science, there is scope to do project work and group practical work in the laboratory as well as in the field when a sense of good social habits, attitude of fellow-feeling and cooperation as well as mutual understanding are automatically cultivated. The significance can be well appreciated when the students undertake project activity as a part of studies such as field trips and educational visits. In such activities, the spirit of team-work and cooperation is visibly exercised. A good example of cooperative team work is scientist William Harvey and his group of scientists. In group work, the students learn to work as a member of a group, help each other, think together and plan together. This process of teaching science has important educative and cultural value. In project or laboratory work, the students learn to do manual work and are compelled to shoulder responsibilities. Moreover, the attitude of dignity of labour is cultivated. In practical work of science, each student has to do his own job by way of arranging and setting up experiments and collection of data. There is no discrimination on the basis of social status or economic condition; rich and poor, irrespective of family background, have to do manual work in the laboratory.

A scientist is a seeker of truth and scientific facts give a true picture of nature. In scientific pursuits, it requires intellectual honesty at each step. In an experiment, one has to record correct data, collect authentic information and make objective interpretation of observations. Anything other than truth will lead to wrong results. For exploration of the unknown, scientists have to proceed carefully on the basis of the true picture at each stage of the process. Intellectual honesty and love for truth coupled with sincerity of purpose are virtues that are prerequisites in any scientific pursuit. History records that Galilio, even in the face of condemnation and trial for punishment, never lost faith in his conviction because he was convinced of the truth of his observation. It is said that even though he publicly negated his own scientific statement in the trial chamber, he yet

muttered outside "oppur si mouve". Bertrand Russell designates this as the voice of the world. Thus, in science ultimately truth prevails because science is nothing but truth. There can be no better moral value of a subject than this virtue.

Further, science as a subject has two very important virtues peculiar to it. The study of science imparts training in 'scientific method' and develops 'scientific attitude' in the learner. These qualities can be cultivated only through this subject which can qualify the learner to live as truly efficient citizen in a scientific society. In sum, science has established itself as the most worthy teaching subject in the modern world not only for its utilitarian values but also because of its disciplinary and socio-cultural values.

2

The Aims of Science Teaching

> If science is to be pursued with full vigour and zest and is to become a mighty force in Indian renaissance, it must derive its nourishment from our cultural and spiritual heritage and not bypass it. Science must become an integral part of our cultural fabric.
>
> —Education Commission (1964-66)

A. The broader perspective of the aims

The aims of teaching any school subject must always be directed towards achieving the aims of education in general. We must remember that whatever subject is taught to the learners, the ultimate aim is to educate the child through the teaching of that subject. Thus, in science education too, we should impart instruction in the subject not so much for the sake of the subject but to serve as an efficient agent or medium for properly educating the child. The aim of education has been defined in different terms by different authorities. But whatever be the diversities in the literature of the definitions, there is no controversy over the common expectation that education must develop to the full, the potentialities of the individual learner in accordance with the general good of the society of which he is a member. The teaching of science as a subject must, therefore, contribute to the all-round development of the child so that he comes out as a socially useful and efficient citizen of the modern scientific world. This aim is, however, too general and too broad to be meaningful in the classroom situation. The broad aims should serve as a frame of reference and should be regarded as directions of growth.

It is, therefore, necessary to formulate suitable objectives to serve as roads towards attainment of the ultimate ends. These objectives should be such that the learners' growth and development are directed towards their realisation and they are practically attainable through the teaching of the subject. The formulation of practically achievable objectives of science teaching brings into consideration a number of factors that are related to the learner and the process of learning. Therefore, while selecting suitable objectives of teaching the subject, we must keep in view the psychology of learning, principles of teaching and the stage of the learner. The formulators of the objectives must take into account not only the need and the abilities of the learner, and the character of the subject but also the demands and expectations of the society. Further, the objectives should be so selected that the progress towards their realisation could be apprised and evaluated. Practically attainable objectives can be formulated not only for teaching of the subject as a whole but also for each topic and each lesson.

B. Preliminary considerations of the aims of science teaching

As has already been stated, the aims should be formulated in the form of attainable objectives. It is no use setting major goals of teaching a subject, just to embellish the pages of the book. Objectives to be of practical value should be worthwhile and attainable, and should be stated in unambiguous and specific terms. But before formulating the objectives, a study of the needs of the individual in his society is essential. These objectives should help and guide us to select and organise learning materials. While selecting objectives, we must take into account the age and the interests of the learners and also keep in view the behavioural change we want to bring about in them.

Keeping in view the general objectives, specific objectives can be framed which may be attainable in the class-room situation. There should be a simple series of specific objectives which can be used by the science teacher in his daily work to give him direction and guidance. Thus, the specific objectives are those which can be measured in the class-room. These refer to learning, skills and interests which can actually be developed through class-room teaching.

The recent trend in science teaching has shown a distinct tendency of general change in emphasis from mere acquisition of assorted facts to the development of functional learning, from unrelated knowledge units to contents logically organised about problems that concern the pupils and from preparation of specialists to general education in science from all. But it does not mean that the future specialists will remain uncared for. The schools must give the future specialists a good foundation for later learning. The modern world demands that every citizen know about science to be an efficient member in the society. It is the duty of the school to maintain a balance and the two jobs must be carried forward simultaneously. But the standard of knowledge and the speed of teaching need not be the same for all. The gifted pupils will be identified and nurtured by giving them opportunities to progress at their own speed. It is the school to which the nation will always look for the future scientists and technologists or specialists in the other fields of science.

About the general education in science to all, the fifty-ninth Year-Book of the National Society for Science Education says that all persons need to know about science "not so much as a great wealth of knowledge as a happy understanding of the nature of science. What everybody needs is a sense of knowledge leading to a sympathy with science and an appreciation of the way the scientists work." Thus, the duty of the school is not only to help the pupils acquire the requisite scientific knowledge but also enable them to appreciate the part science plays in their lives. The school will, during the process of teaching, inculcate the higher virtues of science teaching such as critical thinking, accurate observation, scientific method and scientific attitude. The school cannot evade the obligation of making the pupils aware of the social aim of teaching science. The pupils must be given sufficient understanding of the facts of good and healthy living in the society. They should be explained how the knowledge of science can be utilised for the benefit of the individual and the society.

Since schools prepare the future citizens, it is their duty to equip the pupils properly for their future life. In this modern world, the preparation for life is incomplete without the knowledge

of basic scientific facts and principles and their applications in everyday life. Though the schools must give the future specialists a grounding in their fields of interest, it is not the duty of the schools to prepare specialists. The schools must give more importance to teaching science as a part of liberal education to pupils, since they prepare them for living in this scientific world.

Every teacher who has to teach science in schools, will realise that whatever aims or objectives we formulate, will remain as paper goals, unless the teachers themselves make conscious efforts to achieve them through their teaching. For this purpose, they should employ the modern methods of teaching science, take help of the available aids for teaching science, evolve creative activities for the pupils and try to accomplish the ends as far as practicable under the circumstances in which they work.

C. Aims and objectives of teaching science

The primary objective of science teaching is to give knowledge and information about the world we live in. To live as an efficient member in the modern society, each citizen needs to know some facts of the natural phenomena (living and non-living), laws and properties of matter, and the application of the knowledge of science and the scientific principles that we come across in our daily life. The school science course should therefore be a part of sound liberal education and thus be general, based on humanistic lines so that it may be of value to all. But such body of knowledge or information must be related to and based upon their familiar experiences in the environment. Every pupil must acquire an adequate background of ordered knowledge that is useful in maintaining health, promoting safety, and in understanding the environment. The recent theories and new knowledge is significant and should be included in the science course. This, however, immediately raises the question of selection from the mass of ever increasing scientific knowledge.

One of the objectives of science teaching is to make the pupils understand science in its various aspects. They should be acquainted with the different branches of science which will

enable them to understand and interpret their environment. They should also be made aware of the successes of men in using and exploiting nature. They should know about the things, materials and powers harnessed in nature—the Sun, water, forests, mines, etc.—for the benefit of man. They should also learn about the character of scientific knowledge, how it is developed and used. In short, the science teacher should help and encourage pupils to acquire an interesting and useful acquaintance with all aspects of science, important in the modern world. In a democratic society each individual is responsible in shaping the public policy of a country. Thus every one needs to understand the relation between science and men, and the interplay of scientific and technological innovations and human affairs. Every young man and woman should be able to understand the dependence of any modern society upon the scientific inventions and to realise that science is an integeral part of our modern living.

Science is not just a collection of some isolated and assorted facts and principles. Moreover, knowledge is not static. It may change its meaning and importance with time. Science, to be meaningful and valuable, should be taught as a whole, at the school stage. The pupils should find themselves in a world of related happenings. The facts and principles of science should, as far as practicable, be taught as generalised concepts. There are many facts or events which have fundamental similarities and a common basic explanation. In this connection H.N. Saunders' *The Teaching of General Science in Tropical Secondary Schools* states that if science is taught in this manner, the pupils will discover that "vibrations and movements tend to travel in waves, that living cells everywhere conform to the same pattern, and that every flower the world over, is a variant of even if it does not achieve, a standard arrangement.... A pupil may learn of several extraordinary different instances of resonance, but his amazement at their variety must be supplemented by appreciation of the fact that one explanation is common to all: should understand and be stimulated by, the idea of that one single thread woven through the whole fabric." The Committee on Science Teaching of the National Society for Study of Education (Thirty-first Year-Book, Part I) even goes

to identify the specific objectives of science teaching with the generalisations or the principles such as:

(a) All life comes from life and produces its own kind of organisms.

(b) All life has evolved from simple forms.

(c) All matter is probably electrical in nature.

(d) Chemical changes are accompanied by energy change.

(e) Radiant energy travels in straight lines through a uniform medium.

(f) The energy of solar radiation is continually working changes on the surface of the earth, etc.

All such generalisations or concepts may not be comprehensible to all grade levels. The teachers should plan simple experiences for the pupils keeping these broad concepts in mind. Thus one of the objectives of science teaching is to lead the pupils and acquaint them with the broader concepts, generalisations and outlooks.

The most important objective of school science instruction is to make the pupils aware of the scientific methods of procedure and to inculcate scientific attitude of mind. The school will not only give the pupils adequate scientific knowledge and requisite skill to meet the problem of existence but also train them in proper scientific methods of investigating problems and create a scientific attitude in them. The methods of investigation are as important as the facts themselves. About the importance of training the pupils in scientific method, the Science Masters Association of England reports: "This method should become clear through our teaching, no lessons are given directly on the meaning of scientific method, rather does it become evident from the spirit of our teaching. The method should become a technique—in fact, an attitude towards life." The pupils should be asked to devise and perform experiments themselves, observe carefully and accurately the happenings, collect relevant data free from any bias or prejudice, organise the collected facts systematically, think critically before forming their conclusions. The science teacher should always encourage an attitude of discovery. Such an independent and impartial experimentation helps the pupils to develop a logical mind, critical judgment and the habit of solving problems independently to find answers to

their own questions. This independent way of solving problems will be of great help in their later life.

This, however, does not mean that we are attempting to produce science specialists. The scientific way of handling any problem and a scientific attitude of mind should be inculcated in all individuals in order that they do not accept things on hearsay, propaganda or superstitious traditions but upon conclusions arrived at on the basis of evidence. Even an educator like John Dewey has emphasised method and attitude as objectives of formal education. This, in fact, is the greatest contribution of science teaching. The scientific method is sometimes defined as the systematic process or procedure, where the aim of doing something is combined with the aim of understanding what is done. It should be borne in mind that a mastery of facts, principles and concepts of science will not develop in the learner the desirable outcomes of science-learning such as scientific attitudes, or scientific methods of procedure. The science teacher must deliberately develop these qualities through the process of instruction in the classroom. If the teacher is sincere and tactful, he can, by providing proper science situation, lead the pupils to develop sensitive curiosity to discover the problem to be investigated, to form the habit of seeking evidence before forming conclusions, to accurate observation, to the habit of being patient and to withhold until sufficient evidence is available, to develop the ability to select relevant data, organise them systematically and form conclusions free from bias, prejudice or hearsay. The scientific attitude also includes open-mindedness and respect for others' opinion, but the latter does not mean that the pupils must be so credulous as to take things for granted without adequate grounds.

The impact of modern science on society has raised the problem of acquainting the pupils with the social implications of science teaching. The students of the modern world need to understand and appreciate the dependence of a modern society on science and the changes in the social structure that have been brought about by the achievements of science and technology. They should not only be able to appreciate and wonder at the modern marvels of science but should also understand the social use of the scientific achievements. This can be justified from the

point of view of the fact that modern liberal education has a much wider orientation, and thus, this idea of developing social attitude and appreciation, should be considered as an aim of teaching science. The science teacher should teach science in such a way that the pupils understand the social functions of science, think and act in relation to the implications of science and the society. They should appreciate science as a part of modern living and that science should always be used for the benefit of the society. While learning about the achievements of science, they should be made to realise that the scientific achievements should never be used for the benefit of an individual at the expense of the society. Developing this social aim or the social attitude and appreciation seem to be growing in importance in the present time as a world opinion, since it is seen that the scientific achievements have been directed towards unfortunate ends. It should be the duty of the schools to train the new generations, who are going to be future citizens, to utilise knowledge of science for social good.

A study of the lives of the discoverers helps to appreciate their discoveries better and makes the facts more interesting and lively. It will, therefore, be worthwhile to give the pupils brief biographical account of the lives of the great scientists and discoverers, their attempts to conquer and exploit nature, their attitudes and their sacrifices for the good of the society. They should be made aware of the fact that science is now no longer the job of a single man and that success, in most cases, results from a co-operative search of many; they should also be able to appreciate the difficulty of original thinking and to apprehend how superstitions and wrong beliefs were dispelled by the efforts of the great scientific geniuses like Copernicus Galilio, and others.

What the pupils learn will not be of lasting value if they do not take interest in it. Science materials should be presented in an interesting way so that the pupils are motivated to learn more and more about science. They should be led to find an engrossing interest and joy in studying science. The teacher of science should aim at awakening pupils' natural interest in learning science and about its multitudes of marvellous manifestations that we see everywhere around us. A science

programme can be made interesting by organising science club activities, science fairs, visits to places of scientific interest, field trips and excursions.

In the highly industrialised urban areas, it becomes a problem to utilise the leisure time. Such a state creates the need for opening new avenues of interest to use the leisure hours. Scientific activities provide satisfactory hobbies for this purpose. Moreover, such activities and hobbies give enjoyment and satisfaction which help normal development of the pupils. These creative activities satisfy the psychological needs of the growing boys and girls, and provide healthy pastimes not only to the school-going generations but also to those who have left school and have enough leisure time. The science teachers should realise the importance of this aim of teaching science.

Various commissions, committees, associations and other academic bodies have defined the aims of science teaching. All these reports contain objectives covering areas of knowledge, skills, abilities, habits, interests and appreciation as well as a basis of specialisation and training in better living. The Secondary Education Commission states: "Science in secondary schools is not directed to the production of scientists. Its aim is to give basic understanding and an appreciation of scientific phenomena, biological and physical, which may prepare the 'non-scientists' for a fuller and more complete life. At the same time the course should give fundamental principles to those relatively few who will specialise in science. The teacher should aim at awakening in the pupils a lively curiosity about the natural phenomena arousing and developing their capacity for the practical application of their knowledge, at appreciating the tremendous impact of modern science on all aspects of our life, at interesting them in the human side of all the scientific progress by introducing them to the lives of great scientists. Such an approach will ensure that science becomes a part of 'liberal' education and an instrument for the appreciation of special characteristics of modern culture."

The 'All India Seminar on the Teaching of Science in Secondary Schools' (1956), has stated the aims of teaching general science in Secondary Schools as:

1. To familiarise the pupil with the world in which he lives

and to make him understand the impact of science on society so as to enable him to adjust himself to his environment.

2. To acquaint him with the 'scientific method' and to enable him to develop the 'scientific attitude'.

3. To give the pupil a historical perspective so that he may understand the evolution of scientific development.

The Directorate of Extension Programmes for Secondary Education, Government of India, in its brochure on 'Evaluation in General Science' sets some of the objectives of teaching general science in secondary schools as follows:

1. The pupils studying general science should acquire knowledge of the fundamentals of science useful to all in everyday life.

2. They should develop the ability to apply the knowledge in everyday life.

3. They should acquire experimental skills such as: (a) handling apparatus and instruments; (b) arranging apparatus for an experiment; and (c) preserving apparatus, chemicals, specimens, models, etc.

4. They should acquire constructional skills such as: (a) improving simple instruments and appliances; and (b) repairing certain instruments and appliances of everyday use.

5. They should develop drawing skills such as: (a) drawing and sketching certain objects, instruments and arrangements; and (b) photography in certain objects and specimens.

6. They should be able to locate reliable and recent information from appropriate sources.

7. They should be able to interpret scientific data given in various forms such as tabular, graphical, scientific, etc.

8. They should develop the power of minute observation of their surroundings.

9. They should develop the power of oral expression in science to discuss, argue, describe and raise questions, using scientific terminology.

10. They should develop the scientific method in thinking and action.

11. They should adopt the scie ific attitude in making statements, accepting information and forming beliefs.

12. They should develop interest in scientific reading and

hobbies.

13. They should be able to appreciate the impact of science on life, both personal and social, the struggle through which science has advanced, and the inspiring work of the scientists.

The following similar set of objectives was formulated by the principals of Delhi Higher Secondary Schools in the third summer camp organised by the Extension Department of the Central Institute of Education, Delhi;

1. To develop in the student a scientific attitude.
2. To develop in the student critical thinking.
3. To enable the student to acquire the fundamentals of scientific method.
4. To enable the student to be creative.
5. To develop in the student skill in laboratory techniques.
6. To develop in the student the ability to apply scientific knowledge and principles to problems of everyday life and new situations.
7. To enable the student to comprehend scientific terms, concepts, symbols, various tables and their uses.
8. To enable the student to construct and interpret graphs, diagrams and models.
9. To enable the student to collect and interpret data for the solution of problems.
10. To enable the student to be familiar with the natural resources of his environment and their uses.
11. To enable the student to be familiar with the trends in modern science.
12. To enable the student to appreciate the beauty and order in nature.

The "All India Seminar on Teaching of Science in Secondary Schools" organised by All India Council for Secondary Education, at Taradevi (1956) gave details of the aims of science teaching at different stages of education. These may be summarised as follows:

(a) At the primary level of school education, the aims of science teaching should be to arouse and sustain the learners' interest in nature and in their physical and social environment. Through learning science, the pupils should develop love for nature and observe the things in nature. Science teaching should

inculcate the habits of healthy living, cleanliness and orderly behaviour. It should arouse curiosity and develop in the pupils habit of observation, exploration and systematic thinking. Science learning should also develop their manipulative and creative abilities.

(b) At the middle level, in addition to the above, the pupils should acquire clear information of nature and its events so that this knowledge serves as a basis for learning general science course at the secondary stage. They should develop the ability for generalisation and an understanding of the application of science in everyday life. Science teaching at this stage should aim at inspiring the pupils through the stories of the lives and achievements of the scientists. They should be able to see the impact of science on the individual and social living and also develop interest in pursuing scientific hobbies.

(c) At the high and higher secondary stage, the pupils should be able to understand and realise the impact of science on society and also learn to adjust to the environment. The most important aim is that in addition to acquiring knowledge of science, they should develop a scientific attitude in them and receive training in scientific method. At this stage, they should be familiar with the historical perspective of the evolution of science and its later developments.

The NCERT suggested the objectives of teaching general science at the elementary stage of education covering the age group 6-14 as follows (General Science Syllabus, NCERT, 1963):

1. To acquire knowledge of biological, physical and material environment.

2. To develop skills of solving problems and their application to life problems, to locate problems as well as to design procedures to solve them, collect proper data and methodically organise them, observe accurately and interpret results logically.

3 Develop scientific attitude of mind and inculcate good personal and social habits such as objective and unbiased outlook, love for truth, inquisitiveness, accuracy and precision, right health habits, habit of enquiry, initiative and logical thinking.

4. Develop interest and appreciation such as interest in scientific phenomena and scientific activities as well as scientific

literature and habits, understand the impact of science on every-day life and the society, contributions of the scientists and their sacrifices.

According to the Indian Education Commission 1964-66 (Kothari Commission) the objectives of teaching science at the primary level should be to develop proper understanding of the main facts, concepts, principles and processes in their physical and biological environment and to develop their power of observation. In the lowest class, emphasis should be stressed on cleanliness and good health habits and in the next two higher classes study of personal hygiene and sanitation. In class four, they should be acquainted with the international scientific symbols for measurements and chemical elements.

At the higher primary stage—classes five to seven—the emphasis is to be laid on acquisition of knowledge; and science to be taught as separate disciplines like physics, chemistry, biology, etc. The Commission suggests adoption of disciplinary approach of science teaching rather than general science approach. At this stage, students should be trained to develop the ability to think logically and draw conclusions scientifically on the basis of evidence and observation.

At the secondary level, in classes eight to ten, the Commission suggests compulsory teaching of physics, chemistry, biology and the earth sciences. The approach should be such as to help the students develop discipline of their minds and the knowledge of science acquired should serve as a preparation for higher education in science.

At the higher secondary level, there should be a distinct diversification of courses and the knowledge should serve as basis for further specialisation. In the Commission's words, "science will not be studied on compulsory basis by all students. Those who opt for specialisation in the subject may take all the three electives from science group consisting of physics, chemistry, biology, geology and mathematics. . . . But we are not in favour of rigid grouping and a science biased course can provide for a combination of two science subjects like physics and chemistry with an arts subjects like economics. Similarly, it is possible for an arts student to take up study of physics or biology or any other subject in the science group as an elective."

The aim of teaching science can be summarised under the following categories:

(a) Acquisition of knowledge and information

The students studying science should acquire knowledge of scientific facts, principles and events of nature, living and non-living, rules of health and sanitation and other kinds of knowledge of science that will help the learner to live an intelligent and efficient life in a modern society. Such knowledge must be appropriate to the age, stage and ability level of the learners. Knowledge of science should enable the learner to understand, adjust and if necessary change his immediate environment as required.

(b) Development of interest and appreciation

Since study without interest will not be meaningful and permanent, the teacher should therefore conduct his teaching in such a way as to stimulate interest of the learners in the subject. They must develop interest to pursue scientific activities within and outside the school, read scientific news and literature, organise science clubs and science exhibitions, science competitions and try to apply scientific knowledge in everyday activities. They should take interest to conserve the beauties of nature.

The students studying science should be able to appreciate the contributions of science for the well-being and comfort of mankind and how the ideas and achievements of science have helped the progress of human civilisation. They should be able to realise that the tremendous progress of experimental science, the marvels and wonders of modern science, and the application of science to every field of human activity have marked the present day society as a scientific society. The teachers in their process of teaching should lead the learners to see the impact of science on society and their responsibility as a member of a modern society.

(c) Development of favourable habits

The teachers should see that the desirable need for learning

science is instilled in the learners' minds and that such qualities are reflected in their everyday habits. For instance, science is a pursuit of truth and its pursuit demands intellectual honesty, diligence, perseverance, tenacity, patience, concentration of mind, unbiased judgement, and objective observation. These qualities also help the learners to become self-confident.

Further, studies of science should develop healthy habits. While informing about health and hygiene as well as public sanitation, the teacher should emphasise their application in everyday living. The students should form the habit of taking care of personal health and community sanitation. The knowledge of common diseases and the methods of prevention should enable learners to live a better and cleaner domestic and social life. The science classes in this respect should function as the training ground for good health habits.

(d) Training in scientific method

Through teaching of science, the students should be trained in scientific method of procedure while solving scientific problems. It involves logical steps in the process. It is, in fact, the problem-solving method which involves application of critical thinking and systematic procedure. The scientific method means following certain steps of scientific procedure in sequential order which lead to the solution of a problem. Though there does not appear to be one strictly typical process of scientific method in general, it involves such steps as sensing a problem, defining the problem, analysis, organisation, and experimentation, collection of data, processing and calculating, formulation, of hypothesis and testing, correct interpretation, conclusion and generalisation. The teacher should focus the learners' attention on these processes and train them to follow scientific methods to solve problems not only in the area of science but also social problems.

(e) Development of scientific attitude

This is an important component of the aim of science teaching. The constituents of scientific attitude may not automatically

develop in the outlook of the learners. The teacher will have to make efforts to point out these aspects in the process of teaching science and try to inculcate this outlook in the behaviour pattern of the learners. Scientific attitude refers to critical observation, inquisitiveness, broadmindedness and openmindedness, objectivity in approach, non-belief in superstition and hearsay, belief in proof, trust in correct evidence, respect for others' opinion, faith in scientific method, unprejudiced judgement, belief in cause and effect relationship. Such attitudes are warranted not only in pursuit of scientific problems but also in solving problems at home and in the society. These qualities if developed in the minds of the students and instilled in the behaviour pattern of the learners, solve many problems of individual and social living. Hence, scientific attitude is considered an important constituent of the aims of teaching science.

(f) Development of skills and abilities

Teaching of science should aim at developing in the learners various skills involved in studies of science, such as skills in drawing diagrams and sketches of specimens and apparatus, constructional skills, experimental skills for arranging and organising experiments in science as well as for handling instruments and apparatus skill of observation, and the skill for solving problems.

The study of science should develop the ability to identify a problem, ability to analyse and interpret the problem, ability to improvise apparatus if necessary, ability to generalise and predict results and also the ability to locate source of information relating to the problem at hand. Further, the learners of science should develop abilities to express or discuss on scientific problems, the ability to organise science clubs and fairs and the ability to apply scientific principles in problems faced in life.

(g) Science studies as a basis of future career

In the scientific and technological world of today, there are innumerable avenues where science finds its application. Science,

in addition to being a part of general education, prepares students for future vocations and forms the basis for specialisation in higher sciences. The teacher should be able to select students from his group to be given special training to enable them to pursue specific discipline of science at higher level. Apart from specific studies for technical or vocational career, we need enough manpower for schools themselves.

(b) Provision for utilisation of leisure

In an industrial and technological society, the use of leisure time poses a problem. Science provides a host of technical and intellectual activities which can provide fruitful engagements for leisure. Such activities may range from production and maintenance activities to intellectual activities pursued for pleasure. While teaching facts and principles of physical and biological sciences, the pupils should be encouraged to prepare simple useful materials like soap, boot-polish, ink, etc., or articles like kaliedoscope, simple camera, simple telescope, magnetic compass etc., or engage themselves in maintenance of aquarium, herbarium, nature corner, preparation of charts, models or slides, observation of animal and bird habits, and repairing articles of everyday use and a wide range of similar other activities. The students may also try improvisation of different types of instruments. Such activities provide opportunity for utilisation of leisure and fulfils one of the aims of education.

3

History of Science and its Teaching

Science surpasses the old miracles of mythology.
—Emerson

A. Origin and development of science

The origin of science may be traced back to the earliest times. Its roots go down to the deepest strata of human history and to the darkness long before the beginning of human civilisation. The history of science, therefore, can be said to have begun with the history of human existence. During the enormous stretch of time before the beginning of human civilisation, the earliest homo sapiens invented rudiments of practical rules of craft warranted by the necessities for their existence and survival. It is inferred that even during the period of Cro-Magnon man or the Neanderthal man of the post primate ages, some sort of stone equipment were used for hunting for food. Agriculture was yet unknown. History indicates that these Paleolithic men of the old stone age might have tried to make boats, houses or earthen pots apart from making use of crude stone arms for hunting. But the Neolithic men of the new stone age were comparatively more advanced; they knew agriculture and reared domestic animals, made houses and more or less lived in groups. They probably knew fire-making and crude methods of cooking. They made better flint equipment and even knew the use of copper for making ornaments. Thus, with the passage of time, the early homo sapiens, probabl uiscovered accidently or through crude trial and error, such practical arts as fire-making, cooking, flint sharpening and the processes such

as making earthen pots, weave baskets, build boats and houses, paint curves on flat surfaces, or use of metal for making arms and ornaments. Such abilities imply observation of matter and events and an effort to use them for survival. These activities, thus, may be said to resemble science.

Nothing much can be said of this enormous stretch of time of human existence till about 4000 B.C. By then the men began to live in organised social groups in some geographically congenial places of the earth. History records, that the human civilisation thus began in Mesopotamia, Egypt and other places. These people, among other things, knew the art of building, smelting, time-telling, use of metals; they observed the effect of heavenly bodies as the Sun, the Moon and the stars on agriculture. The people of these civilisations acquired the greatest attribute of science, that is, the art of writing, which their predecessors lacked and for the absence of which nothing much could be known of their achievements.

As mentioned above something recognisable as more or less science began in Mesopotamia and Egypt during these periods. The written records of the study of the movement of the heavenly bodies, architectural designs, metallurgy, medicine, the methods of time-telling, and making of calendar justify this.. The study of astronomy was in progress even before the period of the Pyramids. History reveals that during this period of Mesopotamian and Egyptian civilisation, the Sumerians, Babylonians and Assyrians and the Egyptians made contributions in the aera of science from the utilitarian point of view. The credit for inventing the sun dial and water-clock goes to the Egyptians. The Sumerians are credited with the invention of symbols and scripts for writing. It is said that the Assyrians were better observers than the Egyptians and were able to use arithmetic and algebra. They could name the constellations, taking help of which the Egyptian priests could make annual calendars. Both Assyrians and Egyptians knew weighing and used balances and were familiar with the ideas of mass, length and time. People of these two civilisations were good engineers and knew the smelter's techniques. Egyptians and the Mesopotamians, it is said, even knew the techniques of making glass and glazes for pottery. There are records of advances made in the

area of medicine as well as some other branches of useful arts. Such a state of practical science continued in these and other civilisations till the time of the Greeks around 600 B.C., when the age of theoretical science began; a science based on logic and reasoning.

Similar advances were also made in the Eastern civilisations of China and India during those periods, but there is hardly any good written account of the achievements of these civilisations. We know from whatever record available that the Hindus are credited with the discovery of zero and the decimal system. About the ancient Indus Valley Civilisation, S.F. Mason, in his book *History of Science* states that "civilised society arose in India as it did in Mesopotamia, Egypt and China with bronze-age culture in a river valley. As yet however, not a great deal is known concerning the civilisation of Indus which flourished around 3000 B.C. The people of Indus Valley civilisation had pictographic scripts and decimal numeral system. They used the same fast spinning potter's wheel as the Sumerians and alloyed copper with tin to make bronze; but they wove cotton rather than flax or wool of the West or the silk of the East. About 2000 B.C., however, the civilisation of Indus became extinct." The cause of extinction of Indus Valley Civilisation was probably due to Aryan invasion and establishment of a different social order and a religious and ritualistic philosophy which may not have helped the growth of practical sciences. Excavations at Mohenjo-Daro and Harappa (now in Pakistan) revealed a lot about the civilisation that flourished by the bank of the river Indus, three to four thousand years B.C. It revealed a systematic order of town planning, good drainage system and use of kiln fired bricks indicating high order of workmanship. Various metal vessels, ornaments, figurines indicate their knowledge of forging techniques. Other relics discovered indicate existence of industry, farming and trade. There is no doubt that there were civilisations in China and India as old as the Mesopotamian and Egyptian civilisations and they attained some degree of scientific development in different fields.

As the records available in later periods indicate, the Hindus were already familiar with some of the sciences of the Greeks and probably of the Babylonians too. Some authors believe

that the Pythagorus theorem was discovered in India much earlier There are references of the knowledge of right-angled triangle in "Apastambha-Sulba-Sutra" of fourth or fifth century B.C. or probably even at a much earlier period of time such as the time of "Taittiriya Samhita" and "Satapatha Brahmana." The ancient Hindus were more notable for their work on mathematics and astronomy compared to their achievements in medicine, chemistry and other fields. The important names in Indian science are Aryabhatta, Brahmagupta, Bhaskara, Varahmihira in mathematics and astronomy; Atreya, Susruta and Charaka in medicine and surgery. There were no further developments in science in India during the later periods till the twentieth century when we can now proudly refer to the great talents of Ramanujam, Raman, Bose, Bhaba, Khorana, Narlekar and many other scientists of international repute.

The Greeks looked into the events of the world with a new interest. They were a prosperous race with enough leisure to think. They considered the mysteries of nature from the philosophical point of view and tried to interpret their observations on the basis of reasoning and logic. They gave a new trend to thought, process and scientific pursuits. The science, which was earlier pursued as a learned craftsmanship and from a utilitarian point of view, now received its theoretical and logical foundations. The Greeks were great theoreticians but hated practical experimentation in science. In the different areas of science and philosophy, they produced brilliant theories and thus theoretical science replaced practical arts of the past. They accepted slavery and this led to the separation between practical and intellectual aspects of science. History reveals that even the great thinker, Plato, and his followers thought handling and manipulations were slaves' work. They were interested in using the head and not the hands. But science needs the use of both. Some historians even blame the Greeks for their inaccurate observations and for erecting lofty theories on unsound foundations. For instance, the Greeks assumed the Earth to be stationary and the centre of the universe. That is why probably we saw the downfall of Greek scientific ideas by the sixteenth and seventeenth centuries and the establishment of the new science or modern experimental science.

Though the Greek science ultimately did not stand the test of time, whatever scientific theories this wonderful civilisation gave to the world, held sway for more than twenty centuries. This period has produced great thinkers whose contributions are responsible for changing the entire course of world civilisation of later times. The galaxy of contributors for scientific thoughts especially in mathematics and astronomy, during the Greek period consisted of many geniuses such as Thales, Pythagorus, Anaxagorus, Oenopides, Hippocrates, Democritus, Theodorus Aristotle, Archylas, Eudoxus, Callippus, Hicetas, Manaechmus, Dinostratus, Euclid, Aristarchus, Archmedes, Eratosthenes, Appolonius, Hipparchus, Heron, Meneleus, Ptolemy, Diophantus, Papus and many others.

With the fall of Greek civilisation and the death of the philosophers and the scientists of Greece, a dark period prevailed upon the earth. The progress of civilisation, as if came to a temporary halt in Europe, almost nothing significant could be added to the practical science that existed and the theoretical scientific ideas of the Greeks during the long stretch of about a thousand years till the end of the middle ages. The dark age continued up to the twelfth and thirteenth centuries and there was almost complete intellectual stagnancy, especially in Europe. But the world was now ready for the transition of a new phase of regeneration eventually leading to the emergence of Renaissance in Europe. People began to feel that the new knowledge of the world as explored and their immediate environment as well as the advent of industrial and trade movement, warranted a different approach to science, that is, experimental science. The ancient science could no longer satisfy their physical and mental needs; they began to rely only on what they actually found rather than what the ancients had written or told. Thus, we find that the fifteenth and the sixteenth centuries heralded the dawn of the new science—the experimental science. The development of printing techniques during the later part of the fifteenth century made all kinds of publications easier and the dissemination of ideas became wider. The scientists of the period began to verify the scientific ideas handed down by the Greeks and other ancient civilisations. For example, the Polish priest Copernicus (1473-1543) published his theory establishing the Sun as

stationary and other planets moving around it. This had directly challenged the old order of Aristotle or Ptolemy. The Italian genius of the fifteenth century, Leonardo da Vinci (1452-1519) gave great support to the new approaches to science through his drawings in anatomy and the biological and physical scientific objects. Though known to the world as a great painter, Leonardo was, in fact, a versatile genius. He was not only an artist, but also a scientist, an architect, an engineer and a sculptor. As Prof. Marco Rosci of the University of Turin said, Leonardo's scientific deductions based on life around him were several centuries adead of his time. His sketches and drawings on scientific events and anatomy revealed his superb universal vision.

The scientists of the sixteenth century realised the nature of science but they found it difficult to evolve the right procedure to discover the working or happening of things. The first man to show the world the technique of understanding nature was the Italian genius Galilio Galilei (1564-1642) recognised as the founder of modern experimental science. He taught the world the right scientific attitude, that is, to base science on correct observation and experimentation to prove facts of science. He is famous for his experimentation on falling bodies, work on the pendulum and projectiles and the invention of the telescope. He challenged the Greek ideas on science traditionally prevalent in the society of the time and had to suffer for it. Some historians, however, feel that some injustice had been done to the Greek scientist Archimedes (287-212 B.C.) who actually inaugurated experimentation in science and the world still uses the famous Archimedes' Principle of hydrostatics. In this connection, it may be mentioned that according to history, when the Macedonians conquered Greece, the centre of learning was shifted to Alexandria and other Greek speaking areas. It is said that in Alexandria, science received a practical or experimental bias to some extent. The chemical laboratories there were used for experimentation in distillation, evaporation and condensation as well as on properties of gases.

By the sixteenth century, the world received an intelligible and useful picture of science and nature, and the world in the next three centuries was to see the marvellous advancements in science, shrinking the total knowledge and achievement of all

earlier civilisations spreading over several million years, into insignificance. The study of science from the seventeenth century onwards is marked by the use of all components of scientific process. The scientists of this period observed facts, verified them, measured, timed and repeated them before coming to any conclusion, and finally published results of investigations for discussion in the society. The research trend in science became established. There had been a rapid development in all aspects of human living such as agriculture, medicine, engineering, industry, trade and commerce and these in turn demanded still greater developments in science. The period from the fifteenth to the eighteenth century saw the development of scientific talent which was instrumental in leading us to our present position of living as a member of a modern scientific society. To mention some of the important men of science during this period, we may refer to Leonardo da Vinci, Nicolus Copernicus, Tycho Brahe, Simon Stevin, Galilio Galilei, Johannes Kepler, Evangelista Torrielli, Blaise Pascal, William Harvey, Willebert Snell, Rene Descartes, Otto Van Guericke, Robert Boyle, Olan Roemer, Christian Huygens, Sir Isaac Newton, Hook, Liebnitz, Dionysius, Papin, James Bradley, Joseph Black, James Watt, Scheele, Pristley, Herschell, Lavoiseur, Cavendish, Coulumb, Gilvani, Volta, Rumford, Dalton, Gay-Lussac, Humboldt, Davy, Berzelius, Young, Fraunhoffer, Fresnel, Oersted, Laplace, Ampere, Carnot, Ohm, Gauss, Faraday and followed by such scientists as Mayer, Joule, Helmholtze, Clausius, Thomson, Darwin, Linnaus, Mendel, Bunsen, Kirchhoff, Maxwell, Crokes, Stefan, Boltzman, Hertz, Hasenhort of the nineteenth century. The scientists of the twentieth century hardly need mentioning as they are too conspicuous in the scientific world and we remember them for our very existence in the modern world. Modern science is characterised by its speed and accuracy and now establishes its supremacy over all avenues of knowledge.

B. History of science teaching

In spite of the achievements in various fields of science, even up to the nineteenth century, science did not find its place as a regular part of general education. Science was pursued by only the interested classes of people and lectures or discussions on science

were organised by some universities and social agencies only in places where they had an audience interested in science. But historically speaking, traces of awakening towards learning of science as a part of general education goes back to the early medieval period in western Europe.

After the Greek era, the world passed through a dark age stretching for more than a thousand years without any notable addition to the world of knowledge. Later, Greek learning which spread to the West during the eleventh and twelfth centuries through the Arabs, signalled the dawn of dissemination of new knowledge including science. Such knowledge reached some universities through sporadic efforts. By the thirteenth century, however, the study of Aristotalian philosophy spread to the universities of Western Europe and special emphasis was laid on the study of logic and mathematics. But the period was such that the contemporary Europe and England were under the dominance of religious orders. Society of the time was also orthodox and there was absolute control of the church orders on the society. It was the period when new ideas which went against the prevailing beliefs in the society or contradicted to the slightest extent the religious orders, were not only resisted but were branded heretic. Under such circumstances, the introduction or emergence of new knowledge initially received resistance from the church orders. Two great scholars of the time, Albertus Magnus (Germany, 1200-1280) and Thomas Aquinas (Italy, 1225-1274) endeavoured to make new knowledge of the Greeks acceptable to the Church. Both were renowned philosophers and theologians of the thirteenth century.

However, with the passage of time, the body of knowledge in different fields of learning increased and a tendency arose for experimental studies. Man's ever-increasing knowledge of the world, new explorations on earth, growth of industry and trade necessitated faster progress of science. The first man of science to arouse interest in experimental science was Roger Bacon (1214-1294). He himself was a good scientist and delivered lectures on Aristotle's "physics". He emphasised the values of experimental studies in science over scholastic studies. The next three centuries saw the efforts of a series of notable persons of science, to popularise the study of science from its new practical

outlook, in spite of the resistance from the orthodoxy of Church and society. But the tendency of shifting the emphasis from pure scholasticism to observation and experimentation in science, however, grew more and more popular with time. In 1543, *De Revolutionibus Orbium Coltestium*, an astronomical treatise by the Polish astronomer Nicolaus Copernicus (1473-1543) was published and followed by the publication of *De Fabrica Corporis Humani* of Vaselius. Their ideas heralded new a outlook challenging the older concepts of Ptolemy and Galen. Another rare genius of Europe, who shocked the world with his superb abilities both as an artist as well as a scientist as mentioned earlier, was Leonardo Da Vinci (1452-1519). This Italian artist made science more realistic and vivid through his accurate drawings on anatomy and other mechanical aspects.

While the galaxy of scientific giants in Europe and England of the fifteenth to the eighteenth century continued to enrich modern science unabated, some of these scientists made sincere efforts to popularise learning of science as a part of general education. William Gilbert (1544-1603) of England often quoted as the first modern philosopher in science tried to popularise science education in England. Francis Bacon (1561-1626), a philosopher and an all-round scholar, also strongly advocated the method of experimentation and discovery in science. He emphasised the importance of teaching science and presented his scientific method in his celebrated work *Novum Organum* (1620). Two other philosopher-scientists of the period who tried to popularise science education in Europe were Rene Descarte (France, 1596-1650) and Pierre Gassendi (France, 1592-1655). After the publication of Newton's *Principia Mathematica* in 1687, Gregory, Keill and Whitson were some among the first to popularise Newtonian physics. In modern times, Herbert Spencer (1820-1903) tried to popularise education in science by declaring it as the most worthy of all knowledge. T.H. Huxley (1825-1895) strongly pleaded for the teaching of science for its disciplinary values. While Spencer advocated science as an instrument for physical and moral development, Huxley was a staunch advocate of science for its educational values and urged for its inclusion as a part of general education in the secondary school curriculum. John Tyndall (1820-1893), Professor at the Royal Institute,

London and a colleague of Faraday, scientist of the same period, tried popularising physics as a part of general education. Michael Faraday (1791-1867), who was an experimental scientist, was a strong protagonist of developing scientific mental disposition in the science learner.

But in spite of the efforts of these great men to popularise science as a part of general education, it was yet to gain a place in the regular curriculum of studies. During this period, a number of societies were formed in Europe and England such as "Academie des Sciences" (1793) "Royal Society" (1660) and "Royal Institution" (1799). These societies made significant efforts towards popularisation of science education in universities and schools. This period was also marked by many interesting scientific discoveries and inventions made by some amateur scientists of Europe and England who pursued experimentation in science for their own interest in the subject. Their practical demonstrations attracted attention of the public. Benjamin Franklin (1706-1790), also called the first civilised American, made similar efforts in America. The "Society of Arts" was formed in London and the "Literary and Philosophical Society" in Manchester during the end of the eighteenth century. Then the "Royal Institute of Great Britain" was established in 1799 The "Department of Science and Arts" was established in England in 1853.

It is said that John Anderson was the first to start lectures on experimental physics in the "Mechanics Institute", Glasgow, England in 1823 and Thomas Hall to start the first lessons on practical chemistry in 1847 at the City of London School. By then public seemed to have been conscious to some extent of the new trend in science education as revealed by appointment of committees and commissions to enquire into the state of education in England. Much information in this connection is available in reports of the Royal Commission of Education, Report of Devonshire Commission, Spens Report, Norwood Report, etc. The Royal Commission of Education mentioned about the sorry state of science education in England. It was reported that natural science was taught as an elective to language at Rugby. Later, however, physics was introduced there in 1837 and botany and chemistry in 1859. The Report of the Devonshire Commission

of 1895 contains details of the state of science teaching in the schools of England. It may be mentioned here that introduction of science as a subject in the Oxford and Cambridge universities of England also encouraged the schools to include science as a teaching subject at the secondary level. The report of the Devonshire Commission subsequently led to the introduction of different subjects of science in large number of secondary schools of England. One of the staunch advocates of science teaching of the nineteenth century was H.E. Armstrong who made significant contribution towards popularising the teaching of science in secondary schools. He even developed a method of teaching science which later came to be known popularly as the "Heuristic Method". The Science Masters Association of England published a periodical *School Science Review* which also helped in popularising science education in England and in creating favourable public opinion. It must, however, be admitted that the World War of 1914-18 intensified the importance of science education and the world was convinced of the need for science education in the modern world. During the War, Thomson Committee was appointed in 1916 to study the position of science education in England. Further, the "Norwood Report" of 1943 also dealt with school science education and incorporated recommendations for better science education. Finally, the Education Act of 1944, included necessary provisions for wider science education in that country. The advances of science and technology during the twentieth century and the great scientific achievements on which the modern society has now become dependent, raise no question about its inclusion in today's school curriculum. In fact, science teaching has gained high priority in all the countries of the world.

C. History of science teaching in India

Ancient India made significant contributions to the world in the field of mathematics, astronomy, agriculture and also to some extent in chemistry and medicine. But their progress could not develop beyond a limit. There may be various reasons for this set-back such as peculiar religio-cultural patterns and caste divisions in society, frequent invasions from outside, differentiation between intellectual and practical work (as in case of the Greeks) in scientific pursuits. India then followed the western

pattern in different areas of human activities including education. The modern system of education in India grew during the British period which ultimately replaced the indigenous system of education that was in vogue in India since ancient times. Initially, during the period of the East India Company's rule, there were more proselytising activities by the missionaries rather than interest in education. However, finally due to the combined efforts of the missionaries, government officers and enlightened Indians of the time, modern education slowly spread all over India. Initially, sporadic efforts were made to spread education in definite subject areas. Calcutta Madrasa (1780) is said to have had provision for teaching of subjects like natural sciences, Quran, astrology, law, geometry, arithmetic, logic, rhetoric, etc. The subjects taught in Benaras Sanskrit College (started in 1791) included teaching of medical sciences. Charles Grant who made disparaging remarks about Indian society was also a strong protagonist of modern education for the Indian people. He is often referred to as the father of modern education in India. He pleaded for teaching of English literature, science, philosophy and religion to Indians through the English language. It was actually the Charter Act of 1813, which acted as the turning point in the history of education in India. Since then, India has seen official involvement in the field of education. In the meantime, public opinion rapidly grew in favour of spreading western education and science. Lord Macaulay (Thomas Babington Macaulay) was another strong advocate of western education in India and his "Minutes" of 1835 is a historic document in Indian education. Its effect can be immediately observed in the resolution passed by the Governor-General of India, Lord William Bentinck, in March, 1835, which *inter-alia* contained provision for utilisation of funds for "imparting to the native population, a knowledge of English literature and science through the medium of English Language". Another favourable development during this period was that some English scientific books were translated into Indian languages and these helped the development of interest for education in science. Woods' Education Despatch of 1854 may be said to have laid the foundation for the present system and given a lead for the future educational reconstruction in India. Among other things, it emphasised that the object of education in India should be

"diffusion of the improved arts, science, philosophy and literature of Europe, in short, of European knowledge". The subsequent decades show continued westernisation of the contents of education. Education went on expanding; but science was yet to receive its due share of attention. There had been many committees and commissions which examined the educational functioning as a whole in this country. The many reports recommended quantitative improvements in education in general. Some of the reports revealed the most neglected state of science education in the country. and contained recommendations for imrovement. For instance, the last educational report of the British rule, the report on 'Post-War Educational Development in India' of 1944, commonly known as the 'Sergent Report' envisaging two types of high schools in India said:" The academic high schools will impart instruction in arts and pure sciences; while the technical high schools will provide training in applied sciences and industrial and commercial subjects." The list of common school subjects for both types of schools were mother tongue, English, modern languages, history, geography, mathematics, science, economics, agriculture, art, music and physical training; but science was to be studied more intensively in technical high schools. But in spite of all such reports and recommendations, science was not made a compulsory subject in the schools till very recently.

In the post-independence period the first education commission was the University Education Commission of 1948 under the Chairmanship of Dr Sarvapalli Radhakrishnan. Though the Commission was to report primarily on the university education with needed recommendations, it made valuable recommendations in respect of secondary education also, as it felt the improvement of curriculum and syllabus at the secondary level to be essential for improvement of university education. The Commission recommended inclusion of general science (physics and biology) as courses of study in secondary schools. For first degree courses, the Commission suggested that not less than two special subjects must be studied by science students under group (B) from among mathematics, physics, chemistry, botany, zoology and geology.

Later, in 1953, the Secondary Education Commission, (under

Dr Lakshmanaswami Mudaliar as Chairman) suggested compulsory inclusion of general science and mathematics as core subjects at the middle as well as secondary level. At the higher secondary level, the Commission suggested diversification of courses having science group subjects (three subjects) as optional channel.

Following this, a thorough discussion on all aspects of secondary science teaching was held for the first time in the "All India Seminar on Teaching of Science" held at Tara Devi, Shimla Hills, in 1956 (All India Council for Secondary Education). Such a national level discussion became necessary as soon as general science was recommended as a core subject for the secondary stage of education. The seminar deliberated upon all the related items of school science teaching ranging from the syllabus to scientific hobbies. This was the first agency in India to suggest acquaintance with 'scientific method" and development of "scientific attitude" among the learners as one of the aims of school science teaching.

By now, the importance of science as a subject and its impact on social living began to be appreciated at different levels including political level and in policy making too. It became necessary for the social workers and policy planners to be acquainted with the scientific and technological developments of the time. That is why the Government of India constituted the "Indian Parliamentary and Scientific Committee" in 1961 under the chairmanship of Lal Bhadur Shastri, which studied the problems of science education in schools and made valuable recommendations. A committee on plan projects was also set up in 1962 to study the problems relating to science laboratories in schools and the science apparatus and equipment needs. The Committee submitted its report in the same year. The Planning Commission also set up a committee in 1964 for the same purpose. This committee studied the problem of standard for science equipment, design and layout of laboratories, list of science apparatus as well as fund allotment and purchase procedure. Further, the Indian Standard Institution and Central Scientific Instruments Organisation were entrusted with the responsibility to lay down the standard and specifications of laboratory equipment. In the meantime a team of UNESCO Planning Mission visited

India in 1964 under Technical Assistance Project and after a study of the position of science and mathematics teaching in India made necessary recommendations for improvement of science education at the school level. They suggested teaching science as a separate discipline at the middle stage. Subsequently, the National Council of Educational Research and Training (NCERT) conducted pilot projects on science education at school level in different parts of India for evolving appropriate curriculum, textbooks, and instructional materials for teachers. There was also a top level conference on science education held in 1966 with Dr D.S. Kothari as chairman to work out an effective plan for development of a total curriculum of science education covering different stages. At non-government levels also different agencies started holding discussions and seminars on school level science education in different parts of the country. The All India Science Teachers Association rendered valuable services by organising seminars and conferences where problems of science education were discussed. The NCERT started publishing a quarterly journal entitled *School Science* which helped dissemination of scientific knowledge at the school stage. This agency also sposored publication of *Science Resource Letter*, a small magazine devoted to the improvement of science education in India, produced at the Indian Institute of Technology, Kanpur. In 1964, the Government of India, formulated a scheme called "special centrally sponsored programme for the improvement of science education" to be administered by the State governments. The scheme included three programmes: (1) strengthening of science laboratories; (2) special training of science teachers; and (3) improvement of school libraries.

The programme under "special training of science teachers" contained provision for establishment of an "expert unit" of science in each State which was to grow later into the "State Institute of Science Education". By now such institutes have been established in most of the States. These institutes work for development and improvement of school level science education in the States. The organisation of summer institutes for acquainting teachers of science with the latest developments in these areas, were started in 1963. Science teachers from all over India were benefited by this scheme when summer

institutes were jointly organised by NCERT, UGC and USAID. The NCERT also started the programme of "Science Talent Search" with the objective of identifying and encouraging scientific talent at school level and to draw their active interest in further studies of science.

The greatest impact in the sphere of education in India came from the report of the Education Commission of 1964-66. The Commission was appointed by the Union Government to advise on the national pattern of education and on the general principles and policies for development of education at all stages and in all aspects. Ii is rightly called the report on 'Education and National Development'. The Commission laid great importance to the teaching of science right from the primary to the university stage for development and prosperity of the nation. Thus, it recommended that science education should become an integral part of school education with provision for compulsory teaching of science and mathematics to all pupils as a part of general education during the first ten years of schooling. Further, the Commission recommended that:

1. At lower primary classes, science teaching should be related to the child's environment. The Roman alphabet should be taught in class six to facilitate understanding of internationally accepted symbols of scientific measurement and the use of maps, charts and statistical tables.

2. At the higher primary stage, emphasis should be on acquisition of knowledge and the ability to think logically, to draw conclusions and to make decisions at a higher level. A disciplinary approach to the teaching of science is more effective than the general science approach.

3. A science corner in the lower primary schools and a laboratory cum-lecture room in higher primary schools are minimum essential requirements.

4. At the lower secondary stage, science should be developed as a discipline of the mind. The newer concepts of physics, chemistry and biology and the experimental approach to the learning of science should be stressed.

5. Science courses at an advanced level may be provided for the talented students in selected lower secondary schools with necessary facilities of staff and laboratory.

6. Science teaching should be linked to agriculture in rural areas and to technology in urban areas. But the levels of attainment and avenues to higher education should be the same for both types of schools.

7. The method of teaching science and mathematics should be modernised stressing the investigatory approach and understanding of basic principles. The Commission laid special emphasis on scientific researches and higher level of attainment in science at the university level.

We have now reached a stage when every citizen of India realises the importance of science learning. The impact of science and its achievements has made even a common man of today feel its need. There has been a distinct social urge for a shift in approach to modern education and the older trend and values emphasised earlier are now almost lost. People are now conscious to educate their children in a way so as to enable them to cope with the personal and social problems obvious in a modern complex society due to the influence of scientific, technological and industrial progress.

4

Methods and Procedures of Sicence Teaching

> Man is not born acquainted with sensible objects and their properties and effects; these notions must be gained by experience.
>
> —Liebig

A. The teacher and his techniques

Any teaching procedure centres round three pivotal factors: the pupils, the teacher and the subject. Out of these three, the teacher is the most important factor in the teaching-learning process, since he is the medium of communication between the other two. He teaches the subject to his pupils and has to know not only the subject but also the pupils whom he is to handle. Teaching science to different grades of pupils presents different problems and the techniques adopted for teaching science to the elementary or junior pupils differ from those to be adopted for senior pupils of the higher classes. A group of pupils in a class might vary in age, background, physical and intellectual maturity, skills, abilities and appreciation. The teacher not only has to handle them and teach, but also, to remedy the defects of their previous background. He has to prepare himself to face the questions of the young, inquisitive minds about all sorts of things or natural phenomena they see in their everyday life. The older pupils might be a little critical about the why's and how's of the things that happen. The teacher must try to satisfy these senior pupils approaching maturity and whenever possible, plan suitable experiences for them in order that they themselves find

the reasons. He has to sort out different materials for different grades of pupils, employ various techniques of teaching according to the age, ability and aptitude of the individuals in the group, and devise different learning activities suitable for different groups, or individuals in order to make them actively involved in the learning experiences. The success of the teacher will be revealed by his ability to arouse and maintain interest of the pupils in learning science. He has to stimulate both the more able and also the less able pupils. This obviously demands different techniques of motivation. These, and many other factors that arise during actual teaching, make the task of the teacher a highly complex one.

The teaching of science is not just handing out facts and information of science. It is much more than that. The good aims of learning science should be kept by the teacher before him, and suitable learning experience should be devised for the pupils in order to attain those aims. The science teacher should always keep in mind that the ultimate purpose is to educate the pupils through the teaching of science. Different pupils have different types of natural skill and ability such as inborn knack for constructing 'gadgets', improvisation and manipulative skill, or a natural tendency to 'invent' things. The science teacher should encourage and provide opportunities to these pupils for development of their natural abilities. It is always wise to devise learning experiences in terms of the needs of the pupils and in co-operation with them. The young always love experimenting and doing things. The science teacher has wonderful advantage over others in this respect since this attitude helps learning.

The varieties of instructional techniques that the science teacher employs should be considered as aids to the growth of the learners. Such instructional techniques which the teacher plans to use in his teaching should be flexible and the teacher should be able to make use of different techniques or methods according to the circumstances in case his original plan fails due to any reason. The teacher need not necessarily stick to a particular plan according to which he sought to proceed, he may justifiably move away from the plan whenever a better situation arises in the class-room. In the class, a pupil might raise a question which the teacher never thought of and which may help or upset

the trend of procedure, he originally planned. But the teacher must be skilled enough to handle and to make the best use of such a situation, may be, by proceeding in an entirely different direction. Such ingenuity makes a deep impression on the minds of the pupils and they automatically feel the wonder and delight in learning science. If the question by a pupil is identical with or similar to that which arose in the mind of the original discoverer, the teacher has the opportunity to make the teaching more interesting and stimulating by telling them the life history of the scientist and his achievements. Science teachers must refer to and tell the pupils whenever possible, about the lives of the great scientists, their successes and failures and about their sacrifices for the good of mankind. This is one of the easiest sources for motivating and inspiring the young pupils to learn science.

Science is no doubt, full of facts, principles and concepts, but its teaching is not just giving out information about them. Besides motivating and presenting things in an interesting way, the teacher must be able to create situations for the pupils where they have to think, do and reason out. Each pupil must be involved in the learning process, because learning results from the active involvement of the learner. The science teacher must succeed in making science a part of their life activity and as science teacher he must do his part in planning and administering a continuously balanced flexible programme in science—a programme based on a sound philosophy and providing for the needs, interests and abilities of the learners. Obviously, all science teachers need a thorough understanding of the basic principles that underlie good teaching.

Teaching should begin with something that the pupils are already familiar with or know something about what they are going to learn. Therefore, the teacher should be aware of the present achievements of the pupils, their interests and needs. In order to foster better learning of science, the lessons should as far as practicable be introduced as problems before the pupils. This manner of presenting lessons will encourage the pupils to try for a solution and thereby make them feel important in the learning situation. After introducing the lesson as a problem or a series of problems to be solved by the pupils, the teacher should state the aim of pursuing the particular topic

of study. In actual teaching, the teacher shall make good use of various teaching aids related to the lesson such as sketches and diagrams, pictorial illustrations, charts, slides, or models. Demonstration experiments by the teacher and individual (or group) practical work must invariably accompany or follow the classroom-teaching.

A teacher needs to be skilled in the art of questioning if he desires to make his teaching effective and fruitful. Questioning keeps the class busy, makes the pupils attentive and they feel that they are part of the teaching-learning process. These questions should be relevant, unambiguous and clear in meaning and suitable for the group. It should be a reciprocating process. The pupils should also be encouraged to ask questions because questioning helps to gain co-operation of the pupils. Not only within the class-room but also in all other activities to be performed in connection with the lesson, the pupils should be made to participate actively, so as to make the whole process of learning a co-operative enterprise.

An important aspect of teaching science, which most of our teachers never give due importance, is correlation. Topics taught or the problems pursued in the class should be correlated with their applications and implications in other fields. Class-work should be correlated with the outside world. Correlation of science can be made with other subjects of study or with the different branches of science itself. Correlation of science with everyday life is much more important. Whichever topic is taught, its application in our life should always be pointed out. Science teaching should bring about a closer integration of different branches of science and teaching science as an interrelated process. The 'project' method, which will be discussed later, is an excellent method for bringing unity among different subjects. It is evident that in the modern world science cannot be taught in isolation. Science has influence not only on our life and society but also in the development of other subjects. In turn, these factors affect the improvement of science.

A point in learning science, which our teachers often forget, is the correct use of symbols and scientific expressions. The meaning of symbols, scientific terms and definitions should be based on experience. At the school stage, more stress should be

on the pupils' understanding of the principles rather than the ability to recite long definitions or the power of memorising scientific terms. It is, therefore, advisable that lengthy definitions and difficult scientific expressions should be avoided. It should be considered sufficient if the pupils can state only the essential points of the definition or a principle and understand it properly. The ability to memorise and reproduce definitions is no proof of comprehension. A pupil may be able to recite fluently the second law of motion (Newton's laws of motion) without least understanding of it.

An important function of the teacher in the class-room is to place the pupils in a learning situation and to tactfully throw to them such challenging problems which they would like to solve. The problems should be pre-planned and should be thought-provoking so that the pupils think, reason out and try themselves. As far as possible, the teacher should keep himself in the background giving his pupils the dominant role in the class-room.

B. The choice of method

About the general approach to the teaching of science and the choice of methods, it can be said that there is no set approach which the science teacher must follow. Nor is there a rigidity in method of procedure to be followed by the teacher to achieve the objectives of teaching science. Some objectives are better served by one method of procedure than by another. Some students may be taught more effectively by following a particular method and others by following another method. The use of a variety of methods during teaching helps to avoid monotony. Moreover, the nature of content, too, sometimes determines the method of procedure to be followed. The teachers themselves vary in their liking for different methods. Each objective and even the different topics may demand the use of different ways. Methods are not static. Science is a rapidly growing subject; its teaching demands continued reassessment and periodical review of the contents and the methods of teaching. The science teacher should be acquainted with the use of a variety of methods and procedures of teaching science. But whatever approach the teacher adopts, the methods used and

the aids utilised, the most important factor in the teaching-learning process is the teacher himself.

There are many methods available to the teachers of science. Different methods have been uniquely successful in the hands of different exponents. It is impossible to suggest a particular method or technique of teaching superior to all others. The method or methods to be adopted by a teacher depend on various factors: his talent and interest, his experience, ability to arouse interest and gain co-operation of his pupils, the intelligence level of his pupils, resources of his laboratory or even the situation of the class-room and the school. Moreover, a method proved successful in the hands of one teacher may turn out to be a failure with another teacher. Even the same teacher may have to follow different procedures and methods in different classes or on different occasions in the same class. Hence, it remains for the science teacher to choose one or more different methods of teaching science, which he thinks will be best suited and most effective for a particular group of pupils in a particular situation. But whatever procedure he adopts, it must encourage active participation of the pupils.

Since teachers differ in their ability and so do the pupils they teach, methods, too, vary in efficiency according to situations. The teaching procedure should therefore be flexible and the methods employed should flow easily from one to the other. One need not stick to a particular method of teaching during the whole period. A change from one method to another to create desirable conditions for learning is essential because some methods are effective in developing one kind of values and others may help cultivate a different virtue. For example, no amount of talking or demonstrating how to blow a glass bulb on a tube, will train the pupils in the real skill of doing it. In this case, individual laboratory method has to be followed. To explain a hydro-electric power plant or the working of a sugar factory, the project approach will be more effective. To explain the harmful effect of radiation, a demonstration method would be advisable. On the other hand, for a quick revision or summing up of the previous lessons leading to the present one, the lecture method will be most suitable. Historical or biographical way of developing a lesson arouses interest in the learners but

continued adherence to such a method will turn their interest into boredom. For elementary classes, teaching through exuberant audio-visual aids, field trips, and projects will make learning very effective; for the senior pupils, a bias towards logical treatment will help to satisfy their needs.

It is agreed that one's knowledge of a subject does not necessarily vouch for one's ability to teach it. Teaching a class is a skill of a different order. In addition to a good grasp of the subject, a teacher must possess the ability to teach it well. The efficiency of a teacher is indicated by his ability to impart knowledge and to inculcate in the pupils, the desirable outcome of teaching science. Some teachers have a knack of teaching and possess the gifted ability to arouse interest and enthusiasm in the pupils and to gain their cooperation. Their teaching becomes very effective. But all teachers may not possess such natural ability. They can, however, improve their teaching by study and practice of the various methods or techniques of teaching science. Some of the special methods are discussed below. Each has its merits and demerits. The choice of method or methods will depend on the teacher's experience, interest, ability and the intelligence level of the class he is teaching. Since the approach to the teaching of science and methods to be used depend on various circumstances, the teacher of science should study these factors and choose a particular way of teaching which his experience convinces him to be best suited for the particular situation. When the teacher gains sufficient experience he may, as Saunders has said, "lecture, demonstrate, organise laboratory work individually or in groups; he may encourage the formation of societies and clubs, provide films, lead excursions, set examination papers with questions of various types, recommend additional reading, turn a class into a brains-trust or into a committee to arrange an exhibition and so on." In this regard, the teacher should enjoy full freedom to proceed according to his plan; but the ultimate aim should be an understanding of science and development of the desirable attitudes in the pupils.

C. Special methods of teaching science

1. *Lecture method*

This is the usual class-room 'chalk and talk' method. It is not a

scientific method at all and not quite suitable for teaching science, especially at the school stage. It is advisable to use it sparingly and when the occasion demands. But the method is still widely used in most of our schools for teaching general science. It rarely creates interest or draws attention of the young people. Here the teacher talks and the class listens; thus the teacher is the only active individual in the class and the pupils are passive listeners. The pupils do not have the patience to listen to the lectures all the time. A long, tedious lecture mars the liveliness of the pupils. But a dull lecture is still more harmful; it creates an averse attitude towards the subject. The greatest drawback of the lecture method is that it ignores experimentation—the basis of modern scientific knowledge—and student participation essential for learning science. In a lecture method class, very little is permanently retained by the pupils and there is practically no understanding.

An interesting lecture may, however, be successful in drawing the attention and interest of the pupils or may help in memorising facts but the essential qualities in learning science, such as independent thinking, power of observation and reasoning, are never developed. The method may be effective for superior pupils in the class but fails to benefit the average or the below average pupils. Some authors contend that the method acts as a sort of spoonfeeding to the pupils whose faculties are never exercised. The method is usually recommended for use in higher classes where more able pupils are prepared for college courses. However, the method becomes most effective when as many pupils as possible are drawn into discussion or when accompanied by a good use of the blackboard, other audio-visual aids, and well-planned class-room demonstrations related to the topic. A judicious use of questioning simultaneously may contribute towards its effectiveness.

It cannot be denied that there is still scope for using this method in teaching science. It may be used by experienced teachers in the general procedure. An expert teacher may often use this method to relate thrilling biographical and historical incidents in science. He has to resort to this method, while he speaks of the lives and achievements of the great men of science. It is convenient and speedy for covering the course quickly

and to summarise the essential points of the previous works or to give the class relevant information before the actual beginning of the lesson. In fact, the method is used to introduce a new topic, to state the aim of teaching it, and to open discussions on the result of pupils' practical work. It can also be used for revision of the previous lessons and to refer to books and periodicals in the library. It is the easiest but least advisable of all methods. It lays no strain on the teacher.

2. Historical method

It is believed that childrens' ideas and thinking follow the same historic route of original discovery of a scientific phenomenon. Therefore, some teachers advocate this method of tracing the growth of a theory or a principle through all the stages of its evolution, as a natural process of developing the subject. That is, to start from the discovery of the scientific phenomenon and pass through the actual course of its development from the earliest beginnings. This way of developing the topic is fascinating to the pupils and it appeals to them. The pupils are placed in the position of the successive investigators beginning from the first scientist to the last. The beginners can see how the beliefs of the scientists changed with time and with the discovery of new facts. They will be able to observe how one theory replaced the other with the passage of time and will be able to appreciate the difference between facts and hypothesis. They will realise that a hypothesis or law is true as long as it can explain all observed phenomena. This realisation has important educational value and helps inculcate proper scientific attitude. They can see the whole process of development of a scientific principle or phenomenon from the "original crude attempts at forming hypothesis to the modern refined method of investigation."

Another way of using this method is to start with an interesting incident or story of the lives of scientists leading to a particular scientific discovery such as Archimedes and his bath, or Newton's curious thought over the falling of an apple, which led to the discovery of two most important theories in science. This way, pupils can appreciate the qualities necessary to become a successful scientist. They will also be able to realise that many scientific discoveries were made by chance. This

method can be conveniently used for the exposition of important theoretical concepts in science.

The method has another important implication relating to the human side of scientific discovery. Following this method the teacher can develop and show science as a social venture, and how scientific discoveries have led to the transformation of society. The pupils can also realise that scientists are engaged in tackling problems of immediate interest to every individual and society as a whole.

The greatest drawback of this method is that it is a very slow process of teaching. Moreover, the study of how other scientists worked, though interesting, will not help the pupils, unless they themselves do something. The method receives an important consideration during the making of science syllabi.

3. Biographical method

Young people are usually fascinated by interesting stories. Therefore, this method is often very convenient to teach science. The lives of the important scientists are described in an interesting manner and simultaneously their achievements are discussed in the class. The events of struggle and achievements of the great scientists arrest their attention and makes the study of science interesting. They like to become like one whom they admire. This attitude provides great incentive to the study of science. In fact, extracts from the lives of the scientists can most advantageously be used to introduce many topics. For example, the life of Galileo and the law of falling bodies, the Curies and the discovery of radium, Luigi Galvani and the effect of electricity on muscles, Faraday and electromagnetic phenomena, Harvey and the circulation of blood, Newton and his laws, etc. The protagonists of this method of teaching science suggest that the pupil should try "to project himself into the life of the original discoverer, to experience his successes and frustrations, to appreciate his hopes and disappointments." Some experienced teachers are of the opinion that using the biographical method, a satisfactory syllabus in science could be built up through a study of the lives and works of the important scientists such as Copernicus, Galileo, Gilbert, Harvey, Boyle, Newton, Black, Pristley, Lavoisier, Davy, Faraday, Pasteur, Lister, Flemming, Rutherford,

etc. They expect that a course could be developed around the stories of their achievements.

4. Topic method

About this method, F.W. Westaway says that it is a sort of approach to a subject rather than a method of teaching and that its final aim is to establish the principles from facts rather than the reverse. It is suitable for teaching science in the elementary stage when it is taught as a general science, and is probably practicable only when there is no pressure of external examination. In that case there will be a prescribed course which the teacher must finish. He, therefore, may not be free tc choose a topic in which the pupils are interested or those raised by the pupils themselves. In this method, the teacher selects a topic of general interest and one that is easily experienced by the pupils. He develops around the topic a series of lessons or units. For example, in the topic of the study of 'air' which is of immediate interest to the pupils. Around air, the teacher can develop a series of lessons such as properties of air, properties of its constituent gases—oxygen, nitrogen, carbon-di-oxide, etc.; various appliances using air—barometers, pumps, syringes; uses of air—respiration ventilation, air-conditioning, compressed and liquid air; etc.; air and weather, purification of air, etc. The pupils can easily appreciate the significance of the lessons given to them. It is more real to them when they understand the points of the lesson. They can see the application of what is being taught in their everyday life.

Similar lessons can be developed around topics on water, weather, rocks, soils, metals and minerals, housing and clothing, healthy living, work, energy, plant life, animal life, the universe. The teacher usually discusses and begins from concrete situations. He must at the same time be careful to eliminate things, the discussion of which will be difficult for the grade of pupils he is teaching. In our schools, we usually teach the principles first and then fit the facts to them, but the idea behind this method is to reach the principles from the facts familiar to the pupils.

5. Concentric method

This is not really a method of teaching but a system dealing with the organisation of the course content. It is more concerned with evolving a scheme of work rather than actual teaching and should better be called a concentric system—a system of spreading the whole course (in this case all the branches of science) over a number of years. The system is based on the principle that at the early stages, the subjects should not be treated exhaustively. For example, if we are to teach elementary science over a period of four years, then in the first year very elementary knowledge of all the prescribed branches of science should be given. This serves as an outline or overview of the whole course which the students are to learn in later years. During the second year, some details are added to the content covered in the first year. In the subsequent years, more details will be added filling up the gaps, till all the branches of science are dealt with exhaustively. Thus, in each year the circle of knowledge widens concentrically in accordance with intellectual maturity of the students and their ability to assimilate knowledge at each stage of their progress. The same procedure can be adopted for teaching general science at the high school stage covering a period of three or four years.

This method is superior to the other method of procedure in which one or two subjects are treated exhaustively during the first year and another begun in the next year. It becomes convenient to preserve the continuity in teaching and to keep widening the circle of knowledge concentrically if the same teacher teaches the same class all these years. If the same class is taught by different teachers in successive years, there may either be too much repetition leading to loss of freshness and power of appeal, or omission of some portions which the same teacher would have stressed as more important. Another advantage of this method is that it provides an opportunity for revision of the course covered in the previous years. This serves as an introduction to the new lessons to be taught. But it warrants a highly resourceful teacher to present new problems each year to maintain pupils' interest in the same subject over a number of years.

6. Heuristic method

The word 'heuristic' is derived from a Greek word which means to discover. The meaning itself reveals what this method is designed for. It was devised and developed by Prof. H. E. Armstrong, professor of chemistry at the Imperial College, London. But actually, he borrowed this idea from Prof. Meikeljohn's method which involved discovery and experiment. Prof. Armstrong was interested in school-science; and he got the opportunity of developing and introducing this method in schools while working with teachers of various schools, such as Cowper Str. School, The Finsbury Technical School, St. Dunstan's College, and lastly at Christs' Hospital, London. Prof. Armstrong firmly believed that the true spirit of learning science was original investigation and that the students should themselves discover the facts and principles of science rather than being told about them. He wanted that the students should 'do' themselves rather than 'hear or observe others doing'. The student was placed in the position of the original discoverer to experience as the original discoverer did. In his own words, heuristic methods of teaching science "are methods which involve our placing students as far as possible, in the attitude of the discoverer-methods which involve their 'finding out' instead of being merely told about things."

Thus, in this method each student has to solve scientific problems experimentally, think for himself how to proceed, observe carefully and note down the essential data, analyse the data and draw conclusions. In a way, he is placed in the position of the original investigator. However, he is provided with a sheet of instructions relating to the problem; he has to follow the instructions and do the experiment, take account of what is being done and arrive at a result. He should also be able to understand what bearing the result has on the problem. Heuristic method is indisputably an excellent approach for training students in scientific method. Westaway states the characteristics of this method in the following words: "Essentially therefore the heuristic method is intended to provide a training in 'method'. Knowledge is a secondary consideration altogether. The method is formative rather than informational. Such training, if properly carried out, does cultivate painstaking and observant habits and

encourages intelligent and independent reasoning. It does bring home to boys clear notions of the nature of experimental evidence, and boys do learn that answers to questions can be obtained from experiments they can work for themselves."

The heuristic method may be said to be antithesis to lecture method. Here the students are active participants in the learning process and not passive listeners or inactive observers because the pupils themselves do. The supporters of this method hold that there should be no help from the teachers, no hint, no guidance, no encouragement or disapproval. However, the conscientious opinion is that a little guidance from the teacher in time helps a lot. But a good teacher would not teach; he would limit his activity and provide proper environment so that the pupil finds everything for himself. The method demands an expert and well-trained teacher. A good preparation is necessary on the part of the teacher. He should be equipped with all the necessary aids and textbooks. The success depends upon the teacher's timely help with simple, clear hints which may make even the average pupils interested in investigating scientific problems.

Though the method seems to be expensive and time consuming, the students ultimately gain more, attain more skill and whatever they learn, they learn properly. They acquire a real understanding. The method is educationally sound because the students are active discoverers of knowledge and they find out the truth themselves. If this method is properly followed, it should give the student "more solid foundations for future self education and to inculcate in him the habit of inquiry and research, to enable him to reach, to discover, to listen, to ask or to do himself." In fact, the method emphasises on individual practical work and a scientific attitude. This enables the students to think independently and thus makes them self-reliant. This heuristic attitude in investigating a problem makes the students research-minded and is a useful training for our future scientists. Some people criticise this method by saying that it expects the learners to rediscover certain scientific facts and principles which took centuries even for the eminent scientists to discover; moreover what is the use of rediscovering discovered facts ? The most valuable aspect of this method is the training in 'method'. Some criticise it because it involves a great degree of

artificiality; it is not possible to keep the students sufficiently in the dark or to prevent them from reading books related to the experiment. It is often said that this method presupposes a small class with a gifted teacher.

Science is a practical subject, and since the method emphasises laboratory work the students may get a wrong idea that science exists only in the laboratory though actually laboratories were made for investigating scientific problems—not science for the laboratories. Moreover, the procedure of doing everything in the laboratory can never help cultivate in the students a proper scientific appreciation of their physical and natural environment. The method expects the students to discover things for themselves; but in reality it is not possible. It appears absurd to expect young students to rediscover everything by their own effort. Though the student may appear to have made some original discovery, it is doubtful how much the student really did discover. Westaway says, "A beginner in science may 'discover' a test tube hidden in a drawer but rarely a principle lurking in a group of facts." This false situation, of making the student think that he discovered, what he knows is not true, is harmful. If the student knows the result (which cannot often be checked) of an experiment, which he is to perform, he hardly enjoys the excitement of discovery in it. The situation becomes artificial.

The progress in this method is very slow. Much time is devoted to the process of discovery, the materials to be covered and thus the knowledge to be imparted to students in the specific period of time, cannot be accomplished. If this method is to be followed, there will be a tendency to emphasise those topics or items of a subject which lend themselves to the heuristic treatment at the cost of those topics or items where original discovery is not possible. It suggests that a special syllabus should be designed with items and topics where heuristic approach is applicable. According to the Ministry of Education (London) Pamphlet No. 38 the most important drawback of the method is the fact that "the material upon which they were based was of very small significance in obtaining an understanding of and acquaintance with the salient phenomena of the universe and consequently they failed in the main to arouse the interest and still more to stir the imagination of boys and girls."

This method is not suitable for beginners. In its extreme form it cannot be encouraged. The use of this method in teaching science is advised if accompanied by constant help and guidance of a gifted teacher. But whatever the method, the heuristic attitude should always tinge all our teaching.

7. Project method

This method came into existence as a reaction against the former dull, purposeless and monotonous method of teaching science in which there is no link between the knowledge imparted in schools and the activity outside the class-room. A project, if properly planned, can provide various activities, both inside the class-room and outside. The method consists in building up a comprehensive unit of connected facts around a central theme which may be some matter of scientific interest, a scientific principle or theory or topics of immediate interest to the pupils. The central theme is so chosen that its pursuit provides all sorts of activities inside the class-room as well as outside. A project is usually defined as a piece of whole-hearted and purposeful activity carried to completion in its natural environment. Dr. Stevenson defines a project as a problematic act carried to completion in its natural setting. In case of a group project, the useful task so chosen must be completed in the natural environment working co-operatively.

Essentially, the method is based on the fact that students learn through association, activity and co-operation. The method is psychologically sound. It is commonly experienced that when a fact is presented to us, we usually tend to remember other facts which are either similar to it or connected with it. Because of the principle of association, our interest spreads to matters connected with the original subject and which we would have otherwise ignored. The students also learn related facts besides learning science. The teacher acts as a guide and leads the students, by putting questions at the right hour, to find the facts and principles themselves. Such a project may be chosen from any field of science. The problem may be a constructional type such as building up a school science museum, running a school garden, setting up a simple mateorological station, collecting specimens for science exhibition, arranging a picnic, or it may be of the type

meant for investigation such as the power supply or water supply system of the locality, growing seeds in a box or hatching chicks, the study of plant and animal life of the area. Through each project sufficient knowledge and information can be imparted on topics related to the project. For example, in a simple project like growing seeds in a box, an extensive unit on soil, plant, food, manure, sun rays, temperature and other areas of knowledge related to seed growing can be built up. Similarly, in general science, major portions of mechanics can be developed around the topic 'work'. In India probably hydro-electricity and irrigation are two important developments which can provide a number of themes on which projects can be worked out. By careful planning and organisation of the connected experiences a wide variety of knowledge can be imparted even through simple projects. For example, around a project on 'construction and maintenance of an aquarium', extensive units on food, physiology, behaviour, conditions of aquatic animals and many other biological and natural principles regarding them can be taught. Another example may be a project on rearing birds or other animals which may provide great number of units of teaching such as food physiology, their behaviour, benefit and harm to mankind from them and many other animals habits.

The project method is a suitable method for teaching science in elementary classes. Planning and carrying out a project involves much more work on the part of the teacher than our traditional method of teaching science. The teacher has to be well informed and alert. He must constantly provide encouragement and inspiration so that the original enthusiasm may not slowly fade away. He must be conscious to direct and guide the students to acquire the information they seek and to achieve the end they aim at. The teacher should not only co-operate with the students in their investigation but also see that the students co-operate among themselves and work in groups. To keep their interest alive, the teacher should himself collect articles, reports, illustrations, charts, exhibits, and specimens related to the problem of investigation. He should co-ordinate the activities of the different groups. The school authorities should provide illustrated science journals, teachers' journals and other audio-visual aids to help achieve the end efficiently. The project does not end with

mere investigation. The groups should collect specimens relevant to the investigation, make models and prepare charts, scrap books, newspaper cuttings relating to the project and organise an exhibition, to show the materials for inspection by others. At the end of the project the groups should meet and discuss the problems and their achievements and the leader of each group should read out a written report of his group's activity. The whole class may prepare an article or an essay to be published in the school magazine.

A project helps to widen the mental horizons of the students. They realise that when the question of the use of science for the benefit of mankind is investigated, there arise many other problems besides those of purely scientific interest. The students experience this when they go out to the actual site of the project outside the school. The teacher should point out to the students the social implications of any scientific achievement and also reveal to them the examples of co-operative enterprise in science. It is convenient in this method to choose scientific themes of common interest to the students and also of use to the community. In such a topic, the interest of the students is spontaneous. Within the framework of the same scheme, tasks can be provided to suit the students of different tastes and aptitudes. The most sound aspect of it is the co-operative activity of the students who get to know each other more closely. Moreover, they come in contact with other people and realise that they have to be friendly with the common people of the area and achieve their co-operation too, but for which it may not be possible to complete the project successfully. This method helps to correlate school life with the outside world and brings students in direct contact with the real situations. Such an experience enables the students to make a realistic approach to the other problems as well. The method develops a sense of responsibility, self activity, initiative and an eagerness to learn more. It also makes them careful and accurate observers. They enjoy their learning for the sense of discovery in their learning. The method inculcates the habit of creative thinking and organising knowledge in a scientific way. It provides excellent avenues for correlation of subjects. In such a project students learn a good deal about science and other subjects and also get first hand knowledge of the facts

and materials. In pursuing a project, the students realise the importance of theoretical knowledge needed for practical work. The method involves a great deal of work and ingenuity of the teacher and the efficiency of this method depends on the honest labour of the science teacher.

It is an expensive method and works best with small classes where ample physical resources and sufficient time are available. The method was once widely used in the USSR and also in Scandinavian countries and the USA. It is said that the method gives the students superficial knowledge of many things but leaves an insufficient basis of sound fundamental principles. This is why the method was abandoned in USSR in favour of polytechnisation. Many teachers are reluctant to undertake projects as it involves hard work in planning and in carrying it out. Moreover, projects in the hands of inexperienced and unskilful teachers can never be successful; these may rather lead to boredom.

But it must be admitted that the science project has the potential of continuous stimulation and opens avenues for further study and investigation. Our schools never care to provide challenging problems to the more able students. The gifted students should be allowed to pursue scientific projects of their interest, and the school and the science teacher should supply the necessary resources and guidance.

8. Demonstration method

A demonstration, as the word implies, means to show. But in science teaching, it means much more than mere showing. In fact, it is one of the most versatile and useful method of teaching science and serves a variety of purposes. Demonstrations can best be used as a motivating device by introducing a lesson with an interesting experiment which keeps the pupils interested and curious. During the lessons, it can be used for demonstrating principles and their applications while the theory part is being done in the class. It can also be used to verify, substantiate and review. When a problem of scientific interest in the class arises, a demonstration can be used to solve the problem. On the other hand, it can be used to create a problem too. The method provides scope for a good display of objects, specimens and apparatus to the class. It also provides a means for clarifying

experimentally certain parts of the subject as done in the laboratory. Another important purpose for which it can be used is to demonstrate methods and techniques of carrying out scientific experiments. The method is efficient and economic.

In this method the teacher really teaches and is different from the lecture method where the teacher simply talks. Here, the pupils are kept engaged. The teacher must, however, put relevant questions to the class while conducting a demonstration class. Such a procedure activates the pupils' audio and visual senses simultaneously. The pupils are indirectly coerced to take interest and observe carefully; because they expect questions at any moment about the details of the experiment. A lesson conducted by an expert teacher following this method is of worth much above the lessons conducted by other methods. No other method can match it in regard to its usefulness and economy at the same time. However, in any teaching procedure the teacher is the most important factor; a skilful teacher can make his teaching successful even by following a poor technique. For a resourceful teacher, this method is excellent for effecting real learning; he can use it for arousing interest and enthusiasm for learning science and for covering a comparatively larger field.

The demonstration method is usually used when the apparatus is costly and sensitive and there is chance of damage if allowed to be handled by the pupils. There are some experiments which involve danger such as working with very high voltage, x-rays, materials emitting harmful rays, burning hydrogen in air to produce water and are unsuitable for juniors to handle. Such experiments should never be allowed to be performed by the students, but should be demonstrated by the teacher who, too, should take care and precaution while performing such dangerous experiments. The teacher resorts to this method when several connected experiments are to be performed during the course of a particular lesson to arrive at an inference or a general conclusion. The method can also be used to revise a project connected with the lesson.

The following points may be considered as criteria for good demonstration:

(*i*) The demonstration should be tried out in advance so that everything is in working order. The try-out, whether simple or an elaborate one, should preferably be made a short while before

the commencement of the period. The apparatus and materials needed for the experiment should be secured and kept readily available when needed. This is essential to save time.

(*ii*) The purpose of the demonstration should be clear from the beginning, because, very often the haste in performing the experiment or the sight of the complicated apparatus used for the demonstration, shrouds the main purpose for which the demonstration was performed. And the pupils fail to realise the main objective of performing the experiment.

(*iii*) The apparatus and the equipment used in the demonstration should be as simple as possible. It is advisable that the apparatus used be large-sized, because the complexity of the apparatus may often obscure the purpose and it should be observable from a distance. It becomes more lively if the experiment demonstrated is connected with things seen or experienced by the pupils. The demonstration experiment should have link with their practical work in the laboratory in case when both the demonstration and the laboratory methods are used.

(*iv*) Whenever and wherever possible the teacher should ask some pupils to help him read scales, note data or describe the reaction to the other pupils in the class. This enhances the pupil-participation in the class. The teacher must not let the interest of the pupils wane. He should inspire the class as he works, and a sense of dramatic atmosphere should prevail in the class. The teacher should be able to make the class wait in suspense for the result of the experiment and the created atmosphere should make them attend to the teacher's work with interest.

(*v*) While arranging for a demonstration, the teacher should not forget that the climatic conditions affect some apparatus and materials. He should therefore adjust his demonstration to the time and season that suit the performance. For example, demonstrations on static electricity should be avoided during the rainy season or in a very sultry weather, while experiments on ice can best be performed during the hot season. The experiments on heat should better be done in the winter season.

(*vi*) A good use of the black-board should be made simultaneously. The principle or the generalisation arrived at as a result of the demonstration should be summarised on the black-board, and the necessary diagrams drawn. The demonstration

should be supplemented by other audio and visual aids such as motion picture projections, slides and film-strip projections, pictures, illustrations, charts and relevant lectures.

(*vii*) A good method is to place all the apparatus and equipment in order on the table before the demonstration starts. The demonstration table should be a little higher than the pupils' desk but not too high. Usually, the apparatus and materials should be placed on the left-hand side on the demonstration table in the order in which these will be shown or used. After use, the apparatus should be transferred to the right-hand side in the same order. The demonstration table should be neat and tidy and should contain only those things which are essential for the demonstration. A clumsy way of arranging things on the demonstration table will confuse the pupils in the same way as a clumsy presentation of a lesson does. Therefore, previous rehearsal of the whole task of demonstration under the existing conditions helps the teacher to conduct the actual demonstration in the class smoothly. This also enables the teacher to ascertain that there is no defective apparatus in the assemblage. It is advisable to keep some important extra parts ready so that the teacher can complete the demonstration even if some parts of an apparatus break or go wrong during demonstration. An expert teacher with common sense can draw useful conclusions from an experiment which failed to work, in spite of the careful efforts. Or he may, on the other hand, put such questions to the pupils which may lead them to find out the reason for failure. A teacher with presence of mind can make the class most active even when the demonstration fails rather than an inexperienced and unskilled teacher who performs and completes the demonstration successfully but without proper spirit that underlies a good demonstration. An inadequate and faulty apparatus may sometimes provide an expert teacher, a good scope to show his skill and ability.

(*viii*) It should be remembered that what appears to be a common and simple idea to the teacher may be quite new and even difficult to some pupils and vice versa. Therefore, all the implications and important points of the demonstration should be indicated to the pupils during the demonstration. If necessary, these points should be repeated and written on the blackboard.

(*ix*) The demonstration must be visible to all the pupils in the class. There should be adequate lighting on the demonstration table and also in the background. Arrangements should be made so that whenever necessary, extra illumination can be provided. The teacher should take care not to present or place a black thing in front of the blackboard. When lights are used, their placement should be adjusted so that everything on the demonstration table is visible and that no shadows interfere anywhere. If necessary, the pupils should be allowed to change their positions. They may be asked to stand around the demonstration table at a safe and convenient distance. This is often impossible with large classes. The teacher may, if possible and if it facilitates viewing, perform the experiment on one of the front row desks. The pupils may, if necessary and convenient, be allowed to sit on their desks or stand on their stools; but at the same time care must be taken to maintain control of the class so that there is no undue breach of class-discipline. It is advisable to have a large rectangular mirror erected on the wall behind the demonstration table at a suitable angle and at a suitable height.

(*x*) While performing a demonstration, the teacher must be able to show how the particular demonstration fits into the problem at hand. He must also use the blackboard effectively, and must not leave any fact, which is within the power of comprehension of the pupils, unexplained. Through the demonstration, he should lead the pupils to arrive at the generalisation rather than finding the generalisation himself. The pupils should be asked to take careful notes of the data which are needed to arrive at the generalisation.

(*xi*) The vital point which the teacher must always remember is the fact that, judicious amount of questioning must accompany a demonstration. Here lies the importance of talking during a demonstration; talking not for the sake of talking but to make the teaching of science through demonstrations more useful and more effective.

In many respects this method is more advantageous than the other methods. It not only economises in cost but also in time. The most important fact is that the pupils can see what actually is happening. If properly used, the method can make the learning of science interesting. The teachers should, at the end of the demonstration, refer and direct the pupils for further study.

Though the method is very useful in science teaching and no other method can replace it, the success ultimately depends on the teacher. But it must be admitted that it cannot be a substitute for laboratory method, which will be discussed presently.

In fact, each method provides its own kind of experiences. No method is meant to be used to entire exclusion of the other. It is true that the demonstration method of teaching deprives the students of many advantages of the laboratory method such as individual handling of apparatus (learning by doing). It is sometimes criticised for the assumption that all the students in the class can hear and see everything about the demonstration equally well. This is wrong.

9. Laboratory method

In this method maximum pupil activity can be achieved; the students handle the apparatus and carry out the experiments themselves. The method stands in contrast to the demonstration method in that here the students learn by actual doing rather than by observing the experiment done. Moreover, when the students handle and experiment themselves the experience is impressed more firmly on their minds than when they listen to or see from a distance. The young boys and girls are usually fond of doing things themselves. Therefore, the laboratory method of teaching science is psychologically sound as it satisfies the natural urge for activity. The young are curious to know how events occur. In the laboratory they can see and experience how things happen, through specified experiments. Science is a practical subject. Therefore, some practical work in the laboratory or outside is an unavoidable part of learning science as a whole. In fact, experimentation should be considered an integral part of a science programme. Moreover, one of the aims of teaching science is to train the pupils in scientific method. Therefore, it is imperative that some individual laboratory work be done by every student. In fact, the laboratory method should not be considered independently but should form a part of the total science programme.

The practical work to be done by the students should be pre-organised and pre-selected. Usually, high school laboratory work in general science consists in doing some experiments, individually or in small groups. A conscientious opinion is that

individual practical work requiring handling of materials and apparatus is unjustifiable in the elementary grade from point of view of economy. Demonstrations and group project should, however, always accompany the teaching of elementary science. At the secondary level, individual practical work, including activity outside the laboratory, must be done. To make the laboratory method effective, it must be planned, directed and controlled with as much care as in the case of demonstration method.

The laboratory work broadens interest of the students in the science programme because they can see and confirm things stated in the textbook. They also get accustomed to use scientific tools and equipment. In the laboratory they get an environment to carry out scientific activity and get an opportunity to exercise their ingenuity. They learn to work in cooperation with others, which is a necessary tradition in any scientific pursuit. They learn to rely on facts which they actually see happening rather than opinions stated by others. They realise that scientific theories are to be tested by experiment. In the laboratory, students acquire the skills in handling scientific apparatus, reading scales, drawing diagrams and graphs, and other scientific disciplines such as careful observation, collection and arrangement of data, drawing conclusions, taking necessary precautions. They learn to think in the laboratory. They get an opportunity to examine other local facts which they see in their everyday life but not described in their textbooks.

The laboratory experience is pleasant to the students as they can satisfy their sense of curiosity. In fact, they like the excitement and challenge of the unknown, the opportunity to manipulate things and materials comparatively freely. They gain the satisfaction of achieving something tangible. If properly planned, the exciting experience in the laboratory will go a long way to make the students interested in pursuing higher science and take science as a vocation. There may be some in the group who are keen to undertake original experiments; however, the number of such students is very small. They should be allowed to work independently without much interference. Most of the students are either not ready or lack the ability to undertake original work. They will be benefited from specified standard laboratory exercises by following laboratory instructions and

guidance from the teacher. The usual procedure in our schools is to make the students perform some selected laboratory experiments by following instructions and directions given in the book.

Instead of performing the experiments stated in the textbook, for better benefit, the experiments may, if necessary, be little modified to make the experience more effective and varied. Usually in the textbooks some typical experiments are described. It is possible to arrange for a number of similar experiments to be performed by different individuals or different groups of individuals, so that the result collected from similar experiments can be combined to prove or verify a general principle. The experiments should not be too difficult to perform, otherwise the students may lose interest in it. Before an experiment is performed the purpose of doing the experiment should be quite clear to the students. The teacher must see that the experiment allotted to a student is actually performed following proper procedure. Their manipulation and use of apparatus and equipment should be checked in the laboratory. The teacher should discuss with the students the need for care and precaution in an experiment and should also stress the importance of the accuracy of results. The pupils should be told the degree of accuracy of result expected from them. The student must give in simple and clear language, the account of the experiment including the result in their practical notebook and submit it to the teacher for examination and evaluation. The teacher should go through these accounts critically and in detail.

The advantage of this method is that it gives scope for learning by doing and the pupils do much thinking for themselves. They acquire the skill in handling apparatus and equipment, and learn to follow instructions and to record their observations and results. They also learn to organise data and draw conclusions from it. But it is not justifiable to get individual laboratory experiments done by the junior students as it is often found that junior students learn more rapidly from demonstrations. It is an expensive method too. For each experiment, separate set of apparatus and materials are necessary for each student. Many of our schools even do not have a general science laboratory. Some criticise this method as wastage of time and money in comparison with the experiences gained, because all the students cannot be expected to be skilled workers. Others criticise it for

the fact that the scientific method of solving problems in the laboratory is no guarantee that they would be equally efficient in solving problems outside the laboratory.

10. Assignment method

Ideally, in the teaching of science, the theoretical teaching and the practical work should go hand in hand. The practice of doing experiments in the laboratory on some topic or subject about which no theoretical knowledge has yet been given or which was done several weeks back, is most unsound method of teaching science. The teaching of science becomes effective when the theoretical teaching, effective domonstration, and actual laboratory work are combined. The methods discussed so far have failed to take account of this fact. The assignment method is an ideal approach to achieve this combination. However, the teacher who plans the assignments should be able to divide the experimental portion into two parts: the demonstration—experiments which the teacher himself must do because of the reasons discussed under the 'demonstration method'; and the laboratory experiments which can be safely left for the students to perform.

In this method the whole course content is divided into a number of connected portions or assignments. Each assignment is meant to be completed within a specified period which may be a week or a fortnight. The assignment comprises a preparation part and a laboratory part. In each assignment a particular topic of study is taken up and a set of instructions for both the preparatory study and laboratory work are drawn up. Such assignment sheets need careful planning and should be based on a good textbook. The portions of the book to be read and portions to be omitted in the preparation part should be indicated. The important points to be emphasised should be stated and wherever needed the difficult points should be explained. The questions meant to be answered by the students should be so framed as to test their unerstanding of the portions read and should require short answers. Questions should be unambiguous and should be distributed over all the portions read by the students. The students should also be asked to draw diagrams wherever necessary and to give a list of apparatus needed for the experiment to be carried out. In the instruction sheet the

teacher should direct the students to read further in connection with the assignment and the titles of the reference books should be stated.

The second part of the assignment refers to the laboratory work. This part of the assignment should contain detailed instructions about the laboratory work such as, the preliminary say of the teacher in connection with the experiment, instructions regarding the fitting up of apparatus, noting the observations, method of recording the result, precaut ions to be taken, diagrams to be drawn, etc. If such instructions are available in a book, the students may also be referred to the particular paragraphs and pages of that book. But the teacher's own instructions are more useful because he knows his students better and therefore is aware of the detailed instructions suitable for the particular group of students. The instructions should indicate the causes of errors and also how to avoid them. As far as possible the teacher should give his own diagram of the experiment in the instruction sheet instead of referring to the diagram in the books. This enables him to mark the essential points of the diagram by its side.

Such a printed instruction sheet containing the assignment for a specified period is handed to the students about a week before their turn for laboratory work. The students prepare according to the instructions. They read the particular pages of the text or other extra reading material referred to in the assignment, and answer the questions in a notebook. The completed notebooks are submitted to the teacher for examination. He points out the mistakes, corrects them or gets them corrected by the students and takes note of their respective merits. The students who complete the first part satisfactorily are allowed to do the practical experiment. The teacher keeps a record of the achievements of the pupils in their allotted assignments, in progress charts.

The success of this method depends upon properly drawn up assignments. The teacher has to decide the number of such assignments in a year considering the course to be covered and the working days available. He should also be able to decide the number of periods in a week to be reserved for demonstration and for laboratory work. The choice of a good textbook is a difficult task and the responsibility devolves upon the science

teacher. As is obvious from the discussion so far, the method presupposes an expert and experienced teacher.

Since the burden of work lies on the pupils, they become conscious of their responsibility. But this does not mean that the teacher's responsibility is over after he hands them the assignment. The teacher should always be with the students, inspect their work, help them when in need, and see that all the instructions are carried out. He should see that the students maintain the laboratory discipline and complete the practical work including drawing of diagrams in the laboratory. If some students cannot finish in time, they should be allowed to complete the work in spare time.

In this method they get into the habit of reading extra books. This cultivates a good habit and helps widen the sphere of knowledge. The students can proceed at their own speed and they receive assignments according to their ability. Neither the brighter pupils nor the backward pupils suffer. The brighter pupil can do more assignments and the less able one's allowed to try simple assignments. Moreover, the students always find their teacher beside them to help and guide them in need.

Science is essentially a practical subject. Laboratory work by the students is emphasised in this method. Since different experiments are done by students progressing at different speed, large number of the same type of apparatus is not needed for a class. The students can help themselves and can carry on without any laboratory attendant. Proper emphasis being laid on their laboratory rules such as bringing the apparatus from the store, cleaning and replacing them in their proper place, the students learn to work in cooperation and learn to respect manual labour. The use of progress chart enables the teacher to have an idea about the relative merits of his students at a glance. This also enables the teacher to find out who needs individual care. Progress charts also enable the students to know their progress and it is expected that a healthy sense of competition may grow among the students. If followed properly, the method enables the teacher to assess the students' abilities far more correctly then any other type of examination.

It is obvious that this method involves hard work by the teacher who needs sufficient spare time to draw up satisfactory and suitable assignments for the students. A good stock of reference

books on science and a well equipped laboratory is needed. It is felt that it is impracticable with larger courses of study because completion of assignments takes more time than the usual method of teaching. Moreover, the work load of the teacher increases necessitating employment of more science teachers.

It is often criticised for encouraging backward pupils to copy from the notebooks of the more able pupils. This can be checked by putting oral questions to those pupils whom the teacher suspects of copying.

Whatever its disadvantages, the method is very sound and satisfactory and worth trying. If the teacher wants to try this method for teaching science he should work out a scheme for the whole year. He should read books dealing exclusively on this method of teaching science. After gaining experience in teaching science following this method for some years, he will not feel it difficult. Constant attendance, individual care, regular examination and correction of the written work of the students, keeping ready the necessary apparatus and chemicals for demonstration and individual laboratory work, keeping note of records, and filling in progress charts no doubt increase the load of work of the science teacher. But a sincere teacher who believes in effective science-teaching should be glad to take this trouble. The shirkers in the class should be asked to complete the preparation part in his presence, if necessary in the laboratory, and they should be allowed to perform the experiment only after they complete the first part. The effectiveness of this method depends on the sincerity of the teacher. In order that even the backward students do not feel this assignment system hard, the difficult points of the topic should be made clear to the pupils in the demonstration period. As far as possible, the number of questions in the preparation part of the assignment should not be many. These questions should be graded in difficulty.

The methods discussed so far are important for teaching science and it is essential that every secondary science teacher be acquainted with them. A few additional techniques with which the science teachers should be familiar, are mentioned below.

1. Question and answer method

Questioning is an art which requires many years' experience to achieve perfection. This method can be effectively employed in the discussion hour following or in-between lessons. The teacher using this method tries to bring out information from the pupils which they already possess and to organise the knowledge to be imparted. For this, the teacher may bring a written copy of preplanned set of questions to be put to the class. But this method of bringing a written set of questions to the class may make the discussion too rigid and the pupils may take the idea that the teacher lacks mastery. It may be justified from the point of view of the fact that it checks the discussion from digressing away from the main purpose. However, the teacher must have presence of mind to frame and put relevant questions at the right moment accordingly as the circumstances demand, and which may not be possible in the written set of his questions.

In fact, a judicious amount of questioning should always accompany all methods of teaching. A method can be said to be successful when it involves a kind of ebb and flow between the teacher and the taught. But this should not be allowed to go to the extremes. It should neither be too rigid, that is, strictly adhere to a set of written questions, nor should it be permitted to the pupils to put irrelevant and aimless questions haphazardly to lead the discussion entirely off the track.

The questions put by the teacher should be clear, distinct and unambiguous but thought-provoking. They should lead the discussion towards the objective, and should be evenly distributed throughout the class. As far as possible, every pupil should be given a chance to answer. The questions should neither be too easy nor too difficult but should be of appropriate difficulty so as to be relevant to the ability of the pupils. The terms used must be from the content area meant for that grade and questions should be from the topics about which the pupils were taught or which the pupils have read. The main purpose of questioning is to find out what the pupils know and not to examine what they do not know. The questions put to the pupils must interest them, which means that these should be related to the current situation and to the situations or environment with which they are familiar. The success of

questioning becomes obvious if the pupils respond enthusiastically. An expert teacher can devise questions which stimulate thinking and impel the pupils to further study.

2. Textbook method

This is the usual method of learning science by reading a single prescribed textbook. The worst abuse of this method is made where the textbook is the course and where learning of science means reading a portion of the science textbook, and reciting the portion read to the teacher. Many teachers of the old school still follow this method of teaching science. But in spite of the misuse of the textbook, it cannot entirely be dispensed with. If properly used the textbook can become the most important part of science learning. Actually, there should be a number of prescribed textbooks (and not one textbook) for each subject and a good number of other reference books of the same standard. The teacher, too, should encourage pupils to consult different books for the required information and not to stick to a single textbook slavishly. This will help create a worthy habit in the pupils, i.e., the habit of consulting reference books, which our students lack.

3. Reference method

Unlike the textbook method, here the pupils use several reference books in connection with the topic selected for study. The teacher may supply to each pupil a printed or cyclostyled study guide containing the questions to be answered. The pupils then consult a number of reference books instead of a single textbook to find answers to their problem of study. The references may include books on other subjects too, which contain information related to the topic. In addition to various appropriate books on physics, chemistry, biology, geography, and general science, the encyclopaedias of suitable standard should also be referred to.

It is often said that the method is uneconomic for the average and the slow pupils as it entails a great amount of duplicative study. This may be true. But it is also true that a good programme of teaching science is to use a scientifically prepared

textbook for the basic grounding in the subject and a number of good reference books to supplement the basic reading and also to provide for the more able and the interested students. The best outcome of this method is the habit of consulting references and reading extra books on the subject.

4. Contract method

Here the pupil undertakes to complete a contract of work, suitable to his ability and age. Such work is prepared on different levels of difficulty which may vary in quality, quantity, or both. The contracts of lowest difficulty may require the minimum standard of achievement, whereas the more difficult contracts or assignments may demand greater study or activities of higher difficulty. This plan, therefore, cares for individual difference in the ability, interest, etc , of the pupils. But the disadvantage of this method is that some pupils will always try to undertake the contracts of lowest difficulty and then to continue working at the same level of difficulty even though they may have the ability to undertake more difficult tasks. Here, the teacher must come forward to check and to encourage the more able pupils to accept the difficult contracts.

5. Opportunism

The 'Science Masters Association' (later 'Association for Science Education' of England), in their report on the teaching of science in the modern secondary schools, has made a mention of this method. This is not actually a set method in the sense of the methods discussed so far. The success of this way of teaching science depends entirely on the presence of mind and promptness of the science teacher.

Sometimes an unexpected enquiry comes from the pupils and the teacher should take advantage of this opportunity to discuss it, provided the solution is within their power of comprehension or the problem is worth pursuing. The teacher has to decide immediately whether the topic that has been raised by the pupil through his question is worth following or not. If it is too difficult for the age and ability of that particular group of pupils, the teacher should avoid it tactfully. He should avoid

or sidetrack the discussion in such a way that their spirit of enquiry is not thwarted.

This method demands greater insight and broader knowledge of the teacher. This also demands a sense of broadmindedness from the teacher; the teacher must admit his ignorance, in case the question raised by the pupil is beyond him to answer. After all the teacher cannot be expected to know everything in all cases.

5

Models and Innovations in Teaching

A. Teaching-learning process and models of teaching

(*a*) *Teaching, learning and the teacher*: Teaching pre-supposes an environment where learning can take place. It means the creation of a situation which facilitates learning or leads to learning. Teaching and learning are inter-related processes, where teaching involves various activities, and learning the benefit derived from them. Teaching is the process of which learning is the result; the cause which leads to the effect. It includes instruction, principles, teaching materials, methods, models, and innovative devices.

The clientele of the process of teaching comprises human beings with instinctive and psychological characteristics. Hence the teaching-learning process will have to be looked into and analysed from psychological point of view. Teaching is also a socio-cultural process. The class consists of a group of individuals, each of whom is different from the others, physically and mentally. They come of different family cultures and different social environments. There are constant interactions in the class. Group dynamics operates naturally. Teaching is therefore both socio-cultural as well as psychological. Teaching becomes directly concerned with the behaviour patterns of both the teacher and the taught. Classroom dynamics is also affected by external environmental factors.

Teaching is a complex process and involves many factors. It

has, therefore, been difficult to formulate a final and comprehensive definition of teaching. Educational experts and psychologists have been trying to explain the nature of teaching. Studies and experiments are still being carried out. Psychologically, teaching is an interaction between the teacher and the taught and the result of the interaction is expected to bring about the desirable changes in the behaviour of the learners. The educational activities, the instructional materials, principles of teaching, methods, models and procedures will, therefore, have to be designed keeping the psychological implications in view. Teaching, thus, involves creativity as well as use of methods, techniques, study, observation, analysis and experiments. Teaching is considered both an art and a science.

There have been many studies and experimentations to understand the processes of learning and teaching. Various theories on learning and teaching have evolved as a result of those studies and analysis. The theories of learning aim at explaining the nature of the process of learning, whereas the theories of teaching are concerned with effective learning leading to the development of the learner. The theories of teaching have developed on the basis of learning theories evolving from experiments conducted on animals. The teaching principles are then formulated from those experiences for prescribing curricular activities, the teaching techniques, evolving teaching models and techniques for efficient management and organisation of the class which consists of human beings. Learning theories are concerned with the psychological characteristics of the learners and analysis of the nature of learning, whereas teaching theories operate in social and cultural settings. Learning theories explain the interactions among the variables in the learning situations and the teaching theories devise methods and models to achieve effective learning in such situations.

Thus, the teacher, who is the link between teaching and learning, should equip himself with the knowledge of these facts. He should know the theories which explain teaching and learning. After all, the process of teaching in the classroom ultimately means communication and transmission of knowledge and information, concepts and ideas, facts and principles to the learners. The teacher being the agency responsible for effecting this transmission and being the link between the learning

materials and the learners, it is imperative that he keep himself abreast of the modern teaching theories, the teaching models, as well as the latest innovations in teaching practices. Knowledge of the recent developments will help the teacher in making his teaching more effective and to increase his efficiency as a classroom functionary. Such a background will help him solve classroom problems, enable him to organise teaching activities and select instructional designs and teaching models and innovations appropriate for his classroom situations. For the benefit of teachers in general, some of the teaching models and innovations in teaching practices are described in brief in the following pages.

(*b*) *Models of teaching*: It is beyond the scope of this book to discuss the learning behaviour and the different theories of teaching. These are treated in detail in the general courses on educational methodology and educational technology. In this section, some models of teaching deemed useful for a classroom teacher to improve his teaching, will be discussed.

There is a distinction between a theory and a model. In teaching technology, a theory is a system in which the interaction among the involved variables—teacher and the pupils—is described and explained, whereas a model is an instructional design aimed to produce specific change in the behaviour of the subject. The models of teaching can be considered tentative theories of teaching. John P. DeCecco asserts that the best substitute for a theory of teaching is a model of teaching and that in many fields, models are prototypes of theories. It is through the development of teaching models that the theories of teaching evolve. Models of teaching derived from theories of learning help in observing and analysing the teaching-learning situations in the classroom. The experiences gained thereby, lead to the development of the theories of teaching. The model of teaching can, therefore, be conceived as the initial stage of the theory of teaching.

There are many varieties of teaching models developed by exponents and specialists in the field of education and psychology. Teaching models based on different concepts, from traditional to the modern, of the teaching-learning process have developed. New ideas and new views are emerging with the passage of time and, accordingly, new teaching models based on these

ideas are being developed. Researches in education, psychology and educational experimentations have provided grounds for development of ideas related to the teaching-learning process. Each educational model has its own goal and approach. There cannot be a cut and dried model or a set of models in teaching procedures, as the aim of each model is different.

The development of teaching models is a new area in the field of education and there is immense scope for research and development in this respect. Though the knowledge and familiarity with the different kinds of teaching models can help a teacher to improve his teaching, the teacher should try to develop his own teaching model to suit his behaviour pattern and the pattern of the students in his class. Ultimately the teacher will have to depend on his personality and make it his main instrument of instructional procedure. Besides helping the classroom teacher in making his teaching more interesting, economical and effective, the teaching models can also help the educational-planners and curriculum-makers to improve their planning, content, selection and identification of learning experiences for students. The knowledge of teaching models can also identify sources of learning and proper selection of instructional materials and teaching aids like audio-visual aids and teaching machines.

As already mentioned, teaching leads to learning and a teaching model provides the outlines for generating the specific situations to achieve the learning objectives. The model designs incorporate the procedures for creating the sought-for interactions within the classroom environment or any other kind of teaching-learning situation. After all, teaching is the process for generating environment for learning and the experiences provided by the teaching models should succeed in achieving the desired modifications in the behaviour of the learners.

(c) *Types of teaching models:* We have already mentioned that many types of teaching models have been evolved till now. Different authors have tried to organise and classify the different models of teaching. John P. DeCecco has dealt in detail the psychological and the historical models in his book *The Psychology of Learning and Instructions: Educational Psychology*. These will now be described in brief.

Psychological models

The psychological models provide the basis for development of teaching theories. Under the psychological models of teaching, DeCecco has described four models—basic teaching model, computer-based teaching model, model for school learning and an interaction model of teaching. Among these four models DeCecco considers the model developed by Robert Glaser (1962) as the basic teaching model. The other psychological and the historical models are expected to help understand the general applicability as well as limitations of the basic teaching model.

1. A basic teaching model: This model was developed by Robert Glaser. The model provides, as DeCecco qualifies it, an uncomplicated yet fairly adequate conceptualisation of the teaching process. He expects it to be "general enough to cover wide range of instructional behaviour, concrete enough to have practical utility and simple enough to retain." The model comprises four phases—instructional objectives, entering behaviour, instructional procedures, and performance assessment.

(*i*) INSTRUCTIONAL OBJECTIVES refer to explicit statement of instructional objectives to be achieved by the learners after completion of each segment of instruction. This phase also includes description of the tasks and their analysis.

(*ii*) ENTERING BEHAVIOUR refers to the student's level before beginning of instruction. This includes the previous knowledge of the learners, their intellectual ability, and some social and cultural characteristics of their learning ability. This stage implies knowledge of human ability, individual differences, motivational state, and the readiness of the learners to receive new knowledge. This phase, therefore, helps the teacher to select appropriate educational objectives.

(*iii*) INSTRUCTIONAL PROCEDURE refers to the actual teaching activities and procedures. It is the stage of the model where learning actually results. Here, the teaching process is organised in such a way as to achieve the desired behavioural change among the learners. The procedures and techniques must, however, vary in accordance with the instructional objectives sought to be achieved.

(*iv*) PERFORMANCE ASSESSMENT refers to the evaluation of learner's achievement of the objectives initially set forth. This

stage includes the use of tests and observations to assess the performance of the learners. If it is found that their standard of attainment has fallen short of the expected level, the preceding phases may have to be adjusted or improved accordingly. Thus, this stage of performance assessment provides the feed back to the previous components of the model.

The other three psychological models are described below:

2. *A computer-based teaching model*: It is the most complex teaching model developed by Lawrence M. Stolurow and Danial Davis (1965). Here, a computer is used to take decisions and provide actual instruction. It consists of two stages: a pretutorial stage in which it proposes to select a teaching programme for a particular learner in order to achieve a particular instructional objective. This is to be done before the instruction begins. The second stage is the tutorial stage in which the selected programme is put into use and the student's performance is observed to discover if a more suitable programme is needed to replace the original programme. This model of teaching is obviously a highly individualised one.

The pretutorial phase includes decision on instructional objective and taking into account the entering behaviour of the learner, the computer has to search out a suitable programme of instruction for the student. In the tutorial stage, while putting the selected programme to use, it also decides on the changes in the programme to be effected if it is found to be ineffective. The computer monitors the responses of the learners as the programme proceeds.

3. *A model for school learning*: John Carroll (1962) developed this model of teaching assuming that a learner attains a particular instructional objective to the extent that the learner spends time to learn the task. The model does not deal directly with the instructional objectives, but it implies that the instructional objectives must be determined before hand. There is another distinct difference in relation to the basic teaching model, that this model does not provide for a systematic performance assessment. It, however, assumes that the learner must achieve mastery of the given tasks.

This model has five major components. The first component is the scholastic aptitude of the learner which relates to the learning time required by the learner to achieve particular

instructional objective. Perseverence is another component which refers to the time the learner is willing to spend for learning the particular task. This also refers to his willingness to face difficulties and to engage himself beyond the required time, if necessary. The third component is the ability to comprehend the instruction which relates to the intelligence of the learner. These three components therefore relate to the entering behaviour referred to earlier in the basic teaching model.

There are two other components—opportunity to learn and the quality of instruction. Opportunity to learn is the time allowed for learning and the quality of instruction are the facilities given to the learners to learn. It refers to the efficiency in organisation of the teaching situation which facilitates the learners to learn. It depends upon the efficiency and the quality of the teacher and the attention he pays to the needs of the learners.

4. *An interaction model*: This is also called the social-interaction model. Ned Flanders has developed the best model of this type. The model is based on the assumption that teaching activities continue through interaction between the teacher and the taught. He classified the classroom interactive process between the teacher and the taught into ten categories. An observer observes the class teaching and decides after every three seconds, the category which best represents the communication behaviour for that duration. These ten categories are again grouped into three components: (*a*) Teacher-talk component, (*b*) Students-talk component, and (*c*) Silence or confusion.

(*a*) Teacher-talk component comprises the following seven categories:

(*i*) Accepts feeling—the teacher accepts the feeling of the students and explains the point of view in an environment of mutual understanding.

(*ii*) Praises or encourages—the teacher praises or encourages students' behaviour and acknowledges students' responses positively.

(*iii*) Accepts or uses ideas of students—while acknowledging ideas suggested by a student, the teacher builds and develops upon it, supplementing or adding his own ideas.

(*iv*) Asks questions—the teacher asks questions on the content matter or about the procedure and which the student is

expected to answer.

(*v*) Lectures—the teacher delivers lectures in the class giving facts or opinions about the content or the procedure. He also expresses his own ideas and, if necessary, may also ask questions.

(*vi*) Gives direction—he gives direction or command or order as necessary. The students are expected to comply with such directions from the teacher.

(*vii*) Criticises or justifies authority—this is also the stage of assertive self-reference. The teacher makes authoritative statements for modifying students' behaviour to the acceptable pattern.

(*b*) The student-talk component consists of two categories:

(*i*) Students talk-response—here the teacher initiates in such a way as to evoke response from the students. The students, thus, talk responding to the teacher.

(*ii*) Student-talk initiation—in this category the student initiates and talks from his end.

(*iii*) Silence or confusion—there are short durations when there is silence and sometimes confusion. During such periods, communication between the teacher and the taught cannot be understood or recorded by the observer. None of the above nine categories of interaction is, therefore, applicable.

Out of the first seven categories, the first four categories indicate that students' participation is encourged. The teacher applies indirect influence. But in the categories five to seven, the teacher plays the predominant part, influencing the students directly. He talks more and leads the class. Category eight and nine refer to the role of the students only.

Historical models

In order to compare and show the relationship between the traditional concepts of teaching and the basic teaching model developed by Robert Glaser, John P. DeCecco has described three historical teaching models, namely, Socratic model, Classical-Humanist model, and Personal Development model. These are stated below in brief:

1. Socratic model: The great Greek philosopher, Socrates, believed that virtue was knowledge and that knowledge was the

result of diligent enquiries in which one becomes personally involved. He assumed that knowledge cannot be imparted from outside but will have to be developed from within through a series of sequential enquiries. Here, the teacher's role is tc ask questions to be answered by the students in the light of their past experiences. It is the art of questioning which must lead the student to discover the truth. The method is, therefore, dialectic in nature and the instruction progresses through conversation between the teacher and the taught.

The Socratic method is not a method of instruction but a method of enquiry. Socrates did not formulate any instructional objective but desired the students to become efficient enquirers. In this model, students learn concepts through enquiry, but the primary purpose is to develop the skill and the faculty of enquiry in the learners. This model has many limitations, most important of which is the absence of any distinct evaluation procedure.

2. *Classical-Humanist model*: This is the Jesuit model of teaching which flourished from fifteenth to nineteenth century. The method is said to be a product of the Renaissance. The aim of instruction during this period was acquisition of the skill of speaking, writing, reasoning and criticising. The students, however, acquire these skills in the process of learning curricular contents.

It is agreed by all that the Jesuits had an highly developed instructional procedure. They are known to be very good at organising materials, methods and teachers into an effective instructional system. As described by DeCecco, the chief method of presentation in this model is that the teacher studies the assignment in front of the class and the students are expected to repeat this model performance as precisely as possible. This is similar to the demonstration method of teaching already described in an earlier chapter. In this model of teaching, all students are expected to achieve the same objective in more or less the same way.

According to Harry S. Broudy, the most important aspect of the Classical-Humanist model is the method of securing overlapping reviews which immediately follow the completion of the task. In this system, the teacher praises the correct responses and blames the incorrect responses. The system has motivating

characteristic as well as provision for feedback. Though not explicit in the instructional objectives, it is expected that the desirable values and attitudes will evolve from the studied materials. The instructional objects are then evaluated in terms of the performance of the learners.

3. Personal-Development model: The primary objective of this model of teaching is self-development of the learners. In this connection, Arther W. Combs and Donald Snygg suggest that each student should be given the opportunity to think of himself as a responsible and contributing member of the society. They advocate that such an opportunity allows the students to gain self-enhancement through discovery of their talents and abilities. This develops a positive view of the self, an attitude of acceptance and the ability to relate oneself to others in the society. They argue that since the society and the social culture change, and since the individual will have to adjust himself to every changed situation, it is not necessary to define specific behavioural changes in the learner, which may soon go out of date. In their words, "for the good of our society and its members, it is better to wish for intelligent behaviour than for good penmanship or the ability to diagram a declarative sentence or any of the other limited objectives which may or may not be a valuable means of need satisfaction in the future."

A teacher should present to the students material they are ready to receive and which should engender in them "a feeling of pride and satisfaction through its mastery". It is believed that a good teaching method is good human relationship. There are no strict guidelines for teaching method; the teacher may use any method with which he is "comfortable", because the chief motive of learning is "self-esteem and a feeling of adequacy". It is the responsibility of the teacher to adopt materials and method in such a way as to lead the learners to success. Failure leads to humiliation and frustration. Regarding evaluation in this model of teaching, it is expected that the teachers assess students' achievements by standards appropriate to their age and experience. Further, the schools are advised to measure students' success not by their achievement in the school environment only but by the degree to which they use their attainments in everyday life in society outside the school.

The method advocates freedom and flexibility in teaching

and learning for the students as well as the teachers. The students can explore and satisfy their curiosity, and the teachers too are free to employ any teaching method they like or think appropriate. This trend in education originated with the progressive education movement in America during the first half of the twentieth century as a result of the educational reform efforts in that country. Donald Snygg and Arther W. Combs gave the authoritative lead in this philosophy.

Other teaching models

In addition to the psychological and historical models, there are a few other teaching models noted below:

(a) Philosophical models of teaching

According to Israel Scheffer, there are three kinds of teaching models under this category—impression model, insight model, and rule model of teaching.

1. The *impression model* of teaching is the simplest kind, the philosophy of which was given by John Locke. Here, it is assumed that the mind of the learner can receive and store external ideas and thus, the teaching process should try to exercise and vitalise the mental powers of the learners.

2. The *insight model* of teaching developed by the Greek philosopher, Plato, is opposite of the impression model and does not believe in the idea that new knowledge can be conveyed to the learner merely through use of words by the teacher. He believed that a teacher's words must prompt the learner to acquire the new knowledge himself. The learners must be induced by the teacher to discover the truth by their own efforts.

3. The *rule model* of teaching is credited to the German philosopher, Immanuel Kant, and is based upon the psychological phenomenon of insight. It emphasises on teaching rationality and reasoning. There are certain rules or principles in reasoning process. The model expects development of reasoning and rules of judgement in the learners.

(b) Modern teaching models

It is beyond the scope of this book to describe in detail all

varieties of teaching models under this category. Bruce Joyce and Marshal Weil have classified the different teaching models into the following four groups according to the objectives:

—Social-interaction teaching models

—Information-processing teaching models

—Personal-source teaching models

—Behaviour-modification teaching models.

The common goal of social objectives of the various models under the first category is to develop efficiency in social interaction among the students. This class includes group investigation teaching model, laboratory teaching model, social enquiry teaching model and jurisprudential teaching model.

The second group also comprises six teaching models—concept attainment model, inquiry training model, inductive model, biological science inquiry model, development model, and advance organizer model. These models aim at giving new knowledge and information providing appropriate environment for the purpose. They also provide opportunity for development of creative thinking, reasoning skill, concept formation and intellectual ability among the learners.

The third group of models aim at creating appropriate environment to help the learners develop themselves and emphasise giving maximum opportunity to them for personal development. There are four different models of teaching in this category. These models propose to develop in the learners such personal traits as social behaviour, self-realisation, creativity and human awareness.

The last group of models, that is, the behaviour modification teaching models is concerned with the modification of behaviour with the help of suitable external environment. The teaching environment is such that the situation leads to the desired change in the behaviour pattern of the learners. Different behaviour psychologists have evolved different teaching models for behaviour modification of the students. The most important among these is B.F. Skinner's operant conditioning teaching model in which the subject matter is so presented as to stimulate the learners to construct responses to such stimulus. The correct response is immediately confirmed by knowing the result and the incorrect response is ignored. The process of operant conditioning has been described in detail under the

section on 'Innovations' in the following pages.

Apart from the varieties of models mentioned above, there are certain other models which can be used for teaching education to train pupil-teachers. Such models are useful for analysing the teacher's behaviour and for identifying teaching problems in the classroom. Some models of this kind help the teachers to understand interactions in the class and the classroom dynamics. Teaching models developed by Ned Flanders, Hilda Taba and others are usually used in teacher education for modification of teacher-behaviour and to enable the pupil-teachers to realise the nature of teacher's activities in the classroom.

B. Innovations in teaching practices

(*a*) *Teacher behaviour and effective learning*

Section 'A' of this chapter explains the teaching-learning process. It is seen that teaching is a system of actions performed to induce learning which is the modification of behaviour in the learner effected through certain activities and experiences. All teaching aims at and is oriented towards producing the desired changes in behaviour of the subject which we call learning. But the teacher who is to operate the teaching process and the learner on whom learning is to be induced are all human beings. It is the inter-personal relationship or the interaction between the teacher and the taught that determines the effectiveness of teaching and learning. Though all teaching aims at producing learning, it may not result in learning. Further, the teaching effect remaining the same, the learning effect may vary depending upon the teacher's personality, teaching ability and the teaching-learning environment. It is an undeniable fact that the behaviour of the teacher significantly influences learning. Whatever be the method or strategy of teaching adopted by the teacher to create a conducive learning environment, it is the behaviour pattern of the teacher and his overall approach and treatment with the students that determines whether the learners can be motivated to learn.

In a classroom teaching-learning situation, there is a constant interaction between the teacher and the taught. Teacher's classroom activities are, therefore, performed in a socio-cultural setting, that is, a social environment. The teacher's classroom

behaviour refers to the acts he performs in order to induce learning. In the classroom teaching-learning environment, the teacher is the initiator and motivator in the stimulus-response activities. The teacher's behaviour is also a function not only of his personal characteristics but also of the environmental situations, pupil-characteristics and many other factors. The theory of teacher-behaviour assumes that the teacher's behaviour can be identified and classified into constituent elements and can be treated for desirable modification of behaviour.

(*b*) *Interaction-analysis and modification of teacher behaviour*
Studies in classroom interaction have thrown much light on the social and psychological climate of the classroom. Teaching is a complex process. From the psychological point of view, it is the process of interaction between the teacher and the learner. The influence of the teacher's behaviour on students' achievement is observed and analysed through interaction-analysis procedures. There are various studies in this area. A popular system of interaction analysis is that of Ned A. Flander's ten-category scale for observing classroom verbal interaction. Such studies help in devising procedures through which we can bring about desirable changes in the behaviour of the teachers for developing their teaching skills. These feed-back devices in training technology are effective in improving teaching efficiency of the pupil-teachers. The innovations are, however, based on the assumption that if we create a proper situation, we can achieve the desired modification in the behaviour pattern of pupil-teachers. Some such innovations are described in the following pages.

Simulated social skill training

This is one of the innovations where a classroom environment is created artificially for the purpose of effecting desired modification in the behaviour pattern of the teacher. The Simulated Social Skill Training (SSST), also called role-playing, is an artificial teaching situation where the pupil-teacher plays the role of a teacher in his own group, as if he is acting in a drama. The purpose of the simulated teaching situation is to induce the desired behavioural changes in the role-playing

teacher. In our usual teacher training courses there is no chance for inducing behavioural changes in pupil-teachers under training. As we know, teaching is a social process but learning is a psychological phenomena. The SSST situation provides an opportunity for the pupil-teachers to modify their behaviour and prepares them to face and adjust to the actual classroom situation. This mechanism assumes that there are some desirable behaviour patterns which are conducive for effective teaching, and that the behaviour of the teacher is modifiable with the help of feedback received during the simulated teaching practices by the teacher among the group. It is also assumed that the social skill of the teacher can be improved by his practising in an artificial situation as a teacher in the group. During his role-play, the observer identifies the desirable behaviours relating to the teacher concerned. The teacher then practices those patterns. The SSST technique develops the socio-cultural skill of teaching required in a classroom before the teacher goes for actual classroom teaching.

A fresh teacher may not be able to conceive the complexities of classroom dynamics. He is yet to be accustomed to the social interactive processes that go on in a classroom. Further, there is no possibility for a fresh teacher to realise the problems that develop in a classroom nor is he familiar with the occasional embarrassing situations that arise there, because he has never faced such situations before. It may therefore be difficult for a fresh teacher to manage the class and to organise his teaching appropriate for the particular group of learners. The SSST is a training which prepares pupil-teachers in an artificial classroom situation and equips them with the techniques and tools so that they can face the real classroom situations with confidence.

In an SSST situation, each pupil-teacher acts as a teacher, a student and an observer of the classroom dynamics. The part to be played by a pupil-teacher in the simulated situation as a teacher, a student and an observer or critic, is planned. A pupil-teacher conducts a lesson in the role of a teacher. The observers evaluate the teacher-effectiveness of the acting teacher. Their observations are discussed at the end of the class and the pupil-teacher is informed of his strong and weak points. Suggestions for improvement are tendered. These operations are repeated with different actors, for different lessons and for the social

skills desired to be developed in the pupil-teacher. Such situations give him an insight about what may occur in an actual classroom situation and prepare him to handle classroom behaviour problems.

An SSST situation provides opportunity to observe how a teacher behaves while conducting the class. The role playing teacher becomes aware of his deficiencies as a teacher and realises the importance of modifying his behaviour. The advantage of the SSST situation is that the pupil-teacher can foresee the behavioural problems that may arise in a class and develops in him such qualities which will enable him to encounter the same or similar situation arising in a real classroom. This is a situation which links theory with practice. When a pupil-teacher faces a problem-solving situation artificially created in the drama of classroom teaching, he prepares himself to face similar problems in a real classroom situation.

Team teaching

Team teaching can be considered an innovative procedure in organising teaching rather than a method or technique. It is an instructional design which involves a group of teachers jointly responsible for planning and instruction of a particular course content. The way in which the team of teachers operates constitutes team-teaching. A teaching team is a unit of a small faculty group jointly responsible for teaching a distinct group of students to whom the teacher-group will teach and also other non-professional persons who assist the teachers and the students. The number of teachers in the faculty group may vary from two to six or seven and the team cooperatively prepares and develops the instructional programme. The different grades of teachers in the team may have different responsibilities. There may be a team leader, senior teachers and the team teachers. The team-teacher has direct contact with the learners as he actually teaches the students in small or large groups depending upon learners' common 'entering behaviour'. The senior teacher supervises and coordinates teaching activities. The team leader has the overall administrative, supervising and coordinating responsibility. The description above indicates that the team-teaching approach is an advantageous model for training new

teachers and for inservice training of working teachers. The purpose of team-teaching is to help teachers solve their own teaching problems. The scheme also provides the less skilled or less experienced teachers to observe highly skilled or more resourceful teachers at work. This helps improve their competence. The group working system helps behaviour modification of individual teachers. Further, the team-teaching arrangement provides opportunity for utilising the capabilities of each teacher as he gets the opportunity to plan instructional programme and also to teach in the area of his specialisation. Since aptitude and knack varies with teachers, one teacher may be more skilled in presentation through verbal deliberation or through group discussion, and the other may be better in laboratory work or in presentation through use of audio-visual aids while still another may be more interested in testing and evaluation. A good team-teaching programme must consider this fact and utilise the individual teacher's talents to an advantage.

A team-teaching programme is based on the teaching objectives, need of the students, their entering behaviour and the techniques proposed to be used in teaching. The size of the class and duration of the teaching period can vary accordingly. A team-teaching programme gives emphasis to joint team work in planning, teaching and evaluating rather than the individual teacher. Yet, the professional autonomy of each teacher is always protected by the team and the opportunity of using the special ability of each teacher is never missed.

As in all other instructional programmes, there are difficulties faced by the team. For instance, it may not be easy to find an appropriate team leader or teachers who could function harmoniously and maintain the common philosophy of the group. A team-teaching programme may face difficulty of organisation and adjustment in the routine work-schedule of an institution, or may even create new administrative problems. Some authors believe that it is impossible that a creative teacher may be forced to follow the common interest of the team and hinder his creativity.

The Education Commission, 1964-66, advocated the use of team-teaching approach for promoting elasticity and dynamism in teaching situations. The Commission felt that the practice of team-teaching "breaks down the isolation of teachers, increases

his sense of assurance and makes it easier for him to adventure. It is the basis for all real reform in teaching practice. No worthwhile advance is possible in teaching method unless the individual teacher understands what he is doing and feels secure enough to take the first new steps beyond the bound of established practice. It is easier for a teacher to do so in a small group than when he is working alone. The success of team-teaching in introducing new teaching techniques into some American schools is based on the fact that it is not the individual but the team that is responsible for planning and execution of new methods."

Interaction analysis

The observation techniques were developed for use in analysing classroom teaching activities. Interaction analysis is an observation technique for studying classroom interactive processes objectively and systematically. The system consists of a set of procedures, which includes use of different codes and techniques for observing, recording and analysing classroom interactions between the teacher and the taught. This technique helps in the study of classroom behaviour as teaching progresses and also the teacher behaviour in the class. The interaction analysis technique is based on the theory of teacher behaviour. The specific activities and the event of teaching in the classroom have to be defined and encoded for quantifying the classroom behaviour of the teacher as well as the students. Interaction analysis is therefore the analysis of the process of teacher-taught communication. Results of interaction analysis help solve classroom difficulties and improve teaching effectiveness.

The interaction analysis technique of observing and analysing classroom behaviour can also be used as a feedback for modifying a teacher's behaviour in the classroom. For using the interaction analysis technique to effect behavioural change in the pupil-teacher, his class teaching activities are observed and recorded in accordance with the analysis procedures. After the class teaching is over, the recorded materials are handed over to the practising teacher who becomes aware of his behaviour during his teaching. Thus, the pupil-teacher can improve his teaching on the basis of the feedback. For this purpose, the teacher under training will have to be acquainted with the process of

interaction analysis and the process of encoding and decoding observed behaviour patterns. After decoding the observation characteristics, the pupil-teacher may discuss them with his observer or supervisor and evolve necessary procedures for improvement of teaching. His observation of his own teaching performance provides him the necessary feedback on the basis of which he can modify his behaviour. The teacher may also use a video recorder to record his teaching performance as well as the classroom dynamics to observe his performance. That will help him correct his mistakes and improve teaching skill. The interaction analysis can therefore help a teacher under training to improve his verbal communication with his students and secure greater participation of his students in the teaching-learning process. He can also develop still more appropriate behaviour patterns.

It is imperative that the pupil-teacher have previous training in interaction analysis procedures, knowledge of interaction variables, and the encoding and decoding processes. He should be able to interpret his classroom behaviour in the light of the results of interaction analysis.

The technique of encoding teacher-student interaction during class taking is an intricate process. Encoding is the process applied for recording classroom performances and events, and decoding is the process of interpreting these encoded observations. Encoding should be done by an homogeneous group of teachers. The accuracy of observation of teacher's behaviour will depend upon the training and experience of the observing teacher or teachers.

Micro-teaching

Dwight Allen defines micro-teaching techniques as a scaled-down teaching encounter in class size and class time. It is a real situation of miniature classroom where the pupil-teacher receives the feedback for effecting desired modification in his behaviour. Micro-teaching can be performed under simulated conditions also. A micro-teaching programme can be defined as a "teacher training procedure which reduces the teaching situation to simpler and more controlled encounter achieved by limiting the practice teaching to a specific skill and reducing

teaching time and class-size."

In micro-teaching, the class is reduced to a small group of five to ten students and the teaching duration to five to ten minutes. The content or the size of the topic is also reduced so that the development of a particular teaching skill can be observed. The technique, micro in several aspects, is a highly individualised clinical teaching programme where the teacher is in a real but miniature classroom situation. It is a device to develop the teacher's effectiveness on the basis of feedback. In a micro-teaching situation, the pupil-teacher can apply the previously defined particular teaching skill in a planned series of small-group classes for five to ten minutes. The teaching skill is defined previously in terms of a series of teacher behaviour patterns which are expected to bring about the desired changes in the pupil-teacher.

Micro-teaching improves teaching skill, since at the end of each micro-teaching lesson the pupil-teacher discusses his lapses with his supervisor and then repeats the lesson with another small group on the basis of the feedback. This improves his teaching competence.

An advantage of micro-teaching situation is that it is real teaching, but many of the complexities of a large class are absent. It is not tiring since the content is extremely limited, teaching duration is short and the number of attending students small. Micro-teaching is solely concerned with the development of teaching ability of the teacher and only indirectly relates to the students' abilities. The number of students being very small, the teacher is in a better position in respect of control and management of the class. The teacher can repeat the same lesson as many times as he likes with different small groups until he is satisfied about his performance. The practising teacher gets immediate feedback to modify his behaviour and receives the necessary guidance from his supervisor or observer to that effect. If he uses video-tape or closed-circuit television for recording his teaching, he can himself see and analyse his performance. The micro-teaching technique can also be combined with other innovations as simulated social skill training or programmed instruction to improve teaching competence. It can be practised both by the preservice as well as the

working teachers. This device is meant to improve the teaching effectiveness of the teachers under training.

T-group training

This process is known as the laboratory training model also called a training group or T-group. This technique is primarily meant to be used as a model of teaching to help students understand their behaviour pattern and to develop relationship among them as well as their adjustment ability. This model of teaching therefore endeavours to help the student group to work together towards understanding and adjustment. As a feedback, the technique can also be used for modification of teacher's behaviour.

T-group approach is a simple process compared to other innovations. It consists of a small group of about ten pupil-teachers who informally meet and discuss for two to three hours classroom teaching problems based on their experience of problematic situations they faced in their class teaching. They, however, receive guidance from an experienced teacher trainer. But among the pupil-teachers forming the group, there is no leader nor any specific discussion schedule. Each member of the group is free to express his view. Such discussions develop insight into the problems of teaching in general and each comes to know of the problems faced by others. The training group discussion therefore serves as a feedback mechanism helping the participants see the need for modifying their teaching behaviour. They realise their defects through discussion and can improve their behaviour pattern.

During practice-teaching programmes in training institutions, the training group relating to a subject should meet frequently for discussion under the guidance of the teacher-educator and should lead to feasible solutions to the problems they face in classroom. Such informal meetings may also be organised outside the training institutions. The participants articulate weaknesses in the discussions held in a free and informal environment and are honest and sincere. Such discussions have socialising effect on them and tend to develop flexibility and adjustment in their behaviour pattern. The T-group discussion helps create an attitude for solving problems

of teaching and modify their behaviour. When honestly conducted, the teachers under training can be greatly benefitted by T-group discussion.

Programmed instruction

Programmed instruction is a highly individualised technique for improved teaching. It is a teaching strategy where learning is effected in each learner in a controlled situation even without the presence of a teacher. This strategy makes use of a variety of teaching aids as textbooks, guide books, radio, television, teaching-machines and other modern teaching appliances in addition to the teacher. Programmed instruction is, therefore, a method of providing individual instruction to a student giving him the opportunity to learn at his own pace involving himself alone in the learning process. In this mechanism of learning, the learner knows the result of his effort at every step. The system has developed on the basis of the knowledge of psychology of learning. The technique was developed for student learning, but it can also be used as a feedback device for modification of teacher's behaviour for effecting improved teaching.

The technique of programmed instruction is an application of B.F. Skinner's psychological theory of operant conditioning, which assumes that a learner's behaviour can be shaped into desired patterns with the help of appropriate external environment. In this process, effort is made to achieve educational objectives in terms of behaviour modification. In the operant conditioning mechanism, a stimulus is presented before the individual learner which stimulates response in him and which he puts forward verbally or in writing. The learner immediately comes to know the result of his response and he can confirm the correctness of his answer. But the wrong response is ignored. The correct response is then reinforced. In fact, the system has provision for continuous reinforcement.

Programmed instruction requires that the learner construct his own response to the stimulus given in the form of a question item. The purpose of the stimulus items is to teach and not to test. As such, cues or prompts are needed to facilitate learning as the instruction programme progresses. The success and efficiency of programmed instruction depends on how effectively

the programme is planned. David J. Klaus of the American Institute of Research described the process of programming for an auto instruction device.

The first step in programming, according to him, is to list carefully the specific objectives to be realised in terms of expected behavioural outcomes. After specification of the desired criterion behaviours, the programmer has to decide the kind of programme to be constructed. After identification of the objectives, the next step is to prepare the course outline covering the materials desired to be taught. The course materials may be derived from different sources including related textbooks. If necessary, the content materials may be reviewed by a technical expert in the subject at each phase of the programme. The third step is to prepare draft frames on each unit covering the subject matter as contained in the outline. The draft frames are then edited at three stages, first by a second programmer, then by a technical expert, and lastly by a teacher who is skilled in the use of language. This helps in correcting mistakes, ensuring technical accuracy in the frames, in making the frames interesting in the written form. It is finally the written out frames that make a programme interesting or dull.

After preparation the frames are tried on different trial subjects and are revised after each try. The trial procedure is repeated till the trial subject can proceed through the programme without making any error. After ensuring the validation of the programmes, these are then released for field tryouts. According to Klaus good a programme:

1. requires active responding,
2. requires proper cueing,
3. should be appropriate in context,
4. should proceed in small steps,
5. needs careful sequencing of materials,
6. needs frequent repetition,
7. demands adequate knowledge of the subject matter,
8. should involve less talking but more teaching,
9. should evoke a relevant response,
10. should not provide more cues than necessary,
11. should not assume the learners to have too much knowledge, and
12. should not present two new facts in one frame.

The profusion of teaching-machines in the process of programmed instruction should not confuse the process as an audio-visual device. It is also often feared that auto-instruction system may in future replace the teacher. But in reality, programmed instruction is a teaching technique, aimed at achieving the desired behavioural changes in the learner. In this procedure. it is assumed that the students learn by actually doing and involving themselves. The contents being presented in small psychologically valid sequences, the learner can confirm his progress after each step. The correctness of his response automatically becomes a source of continuous motivation to the learner.

In the programmed instruction model of teaching, the learner learns by his own active participation in the teaching-learning process at his own speed. The learner can also assess his performance at the end of his response and thus, can correct himself. But the effectiveness of learning depends upon the programme and proper use of the teaching tools.

When this technique is used for training pupil-teachers in a training institution, the procedure develops necessary skills in them to identify teaching objectives and translates them into expected behavioural outcomes. While executing a programme, they learn to analyse and arrange the contents in small sequential steps while trying the programme in actual teaching situation and can observe the learning effects. Their observation and involvement provides a feedback to improve their teaching. Their involvement enables them to study how learners with different abilities learn at different rate. This helps the pupil-teacher to realise the dependence of learning on psychological characteristics and plan learning activities keeping in view the individual differences among students.

Initially, the pupil-teachers teach a lesson according to the traditional methods. Then they prepare programme frames of the same content, according to the principles of programming and reteach the same lesson to another group of students of almost similar ability level. The classroom teaching effectiveness in both the cases is recorded and assessed on previously prepared criteria of assessment. The pupil-teacher can now see and compare the difference. The best insight of the teaching-learning process that the pupil-teachers develop is during preparation

of the programme frames. This serves as the feedback to the practising teacher.

The practising teacher receives the required training in planning, organising and preparing the programme frames for actual classroom teaching. He can find out how programmed materials prepared on the basis of students' responses are different from the usual textbooks which are only a source of knowledge items which learners read and try to acquire. As DeCecco states, there is little or no predetermined interaction between a book and the reader in the form of required responses and feedback. Similarly, a lesson-plan is a skeletal outline of teaching materials and activities the teacher uses in teaching. But a programme is actual instruction. A teacher practising programmed instruction technique during his training can realise the difference.

It is essential that the pupil-teachers who practise this innovation during their training for improving teaching competence, are aware of the three types of programming—linear, branching and adjunct auto-instruction. It is not obligatory that a particular type of programming be used under one teaching situation. The teacher can combine the three types of programmes in various ways to tackle the instructional situation.

A programme is 'linear' when there is a single path for the students to follow. Here, the learners proceed from one frame to the next in sequence until they complete the programme. The linear programmes are usually "response-centred" programmes in which each frame contains just enough material to evoke the correct response and permit reinforcement of each response. But some exponents of programmed instruction have shown how a linear programme can also be modified into a multipath programme.

On the other hand, 'branching' programmes are generally "stimulus-centered". The student proceeds responding to the frames till he commits an error. At this point the programme branches off to supplementary materials providing him with the remedial instruction to lead him finally to the correct response. Norman A. Crowder developed a branching technique which he called "intrinsic programming" in the form of programmed book. It is a series of long frames in the pages of a book, each page containing only one frame. The student reads

the page and tries to respond with the correct answer among the three alternative multiple choice items put on the same page. Each alternative refers to a page number which contains another frame. When the student selects the correct alternative, the associated page number refers to the next frame which, in addition to confirming his previous response, introduces new knowledge to him in a continuous sequence as if following a linear programme. If the student choses a wrong alternative, he proceeds to another page referred to in the alternative where his deficiency is met by relevant remedial materials. This is, therefore, branching away from the direct sequence. The pages of the programmed book, thus, cannot be read consecutively. This kind of a programme, where branching programmes are provided in the form of a book, is called a "scrambled book".

In the third type of programming, the adjunct auto-instructional device, the programmed materials are inserted into textbooks, laboratory manuals, etc., as necessary. In the opinion of Sidney L. Pressey, the main burden of instruction should be carried by the conventional instructional materials and the programmed part should deal with only those materials which are difficult and confusing. He felt that adjunct or auxiliary practice materials should accompany the conventional texts for best benefit. This kind of instruction is therefore a combination of both expository as well as programmed type of instruction. A pupil-teacher, while deciding and selecting different kinds of programmes and also their training in preparing these programmes, gives the practising teachers enough scope to benefit by the feedback from their actual use.

6

Scientific Method and Scientific Attitude

While a combination of ignorance with goodness may be futile, that of knowledge with lack of essential values may be dangerous.

—Education Commission, (1964-66)

A. What is science

A discussion on scientific methods and attitudes presupposes the concept of what science is. Science has been defined in different ways by different authors. It has already been mentioned elsewhere that science is not just a body of knowledge as it used to be considered in earlier times; it is a static view presenting science as a host of facts, principles, laws and theories along with the vast lot of systematised information used for interpreting the events in our environment and universe at large. It is true that ever since men tried to understand nature, and to adjust themselves for existence and survival, human knowledge has accumulated. Men then began to study nature's laws and behaviour systematically and classfied the gathered knowledge for convenience. But under the current wider context, science is much more than this. Science is dynamic. It is knowledge as well as the process of its continuous development and refinement. Science is thus both a product as well as a process. It is an endless process of observation, exploration and acquisition through empirical and conceptual means. The characteristics of this process is growth through continuous acquisition, generalisation and refinement.

In science, generalisations often have exceptions. Conclusions

or theories in science are valid as long as they can explain all the known events and behaviours in nature. In this sense, generalisations are tentative. Many laws of science used in experimentations hold good under certain conditions only. For example, the gas laws hold good within temperature constraints. A theory of one time proves invalid at a different time when it fails to explain newly found facts of nature. For instance, Newton's Laws of motion, which are applicable in case of macroscopic bodies with limited velocity, fail application in case of sub-atomic bodies; or his concept of gravitation was not found to be accurate enough to be utilised by Einstein in his field theory of gravitation. The history of science is full of such instances where even long-accepted notions or concepts about nature, living and non-living, were replaced by new ideas and newly found laws, to explain new discoveries and inventions. Science, with the development of accurate technical appliances and invention of improved techniques, has become more numerical, quantitative and objective with time.

B. The scientific method

One of the most significant outcomes of the study of science is training in scientific method now considered as one of the aims of teaching science. The modern educationists, particularly Dewey, advocate scientific method and scientific attitude as objectives of formal education. This is essentially the method that scientists follow or should follow while solving a problem of science and thus, it is also referred to as problem solving method. In fact, the terms 'scientific method'. 'method of science', 'scientific thinking'. 'critical thinking'. 'reflective thinking', 'scientific enquiry'. 'problem solving method' refer to the same process: that is, the method or procedure of solving problems scientifically. Scientific method involves doing something combined with the aim of understanding the thing done. The process of scientific method involves critical thinking, logical reasoning, systematic organisation and understanding at each step of the procedure.

The rudiments of scientific method in their crudest from can be traced back to the beginning of human race. They can be seen in the immature attempts to do something or make something by trying various ways and means until success was

achieved. But the critical discussion and systematic analysis regarding the components of scientific method are of recent origin. Modern scientists have stressed the importance of this aspect of science learning, revitalising the foundations set by a few earlier scientists, especially Bacon, Galilio and Newton. But some modern critics express doubt over the interpretatior of scientific method consisting of a set of definite steps to be followed in sequential order to solve a problem of science. It is contended that there can be different ways of solving a problem scientifically. It is, however, agreed by all that scientific method is an efficient way to solve problems not only in the area of science but also the problems of everyday life. The scientific method obviously begins with a problem.

It may be mentioned here that simply performing an experiment scientifically does not automatically train the learners in scientific method or develop scientific attitude in them. Research studies have revealed that deliberate efforts are needed to facilitate acquisition of scientific method and scientific attitude. Studies have also indicated that direct teaching for scientific method and scientific attitude is more effective than teaching science without considering these outcomes of science learning. It is therefore essential to provide situations and activities to the learners while teaching the subject so that they receive a continuous training in scientific method during the process of learning. An atmosphere of enquiry and investigation involving analytical thinking should prevail during science teaching both in the classroom as well as in the laboratory, or outside the school activities. The teacher should also provide situations where the learners can apply the knowledge and concepts of scientific method and reveal development of scientific attitude in them. He should ask appropriate and leading questions while encouraging the students to explore the problem at hand. Alternatively, he should encourage the students to ask relevant questions relating to the problem that is being investigated or listen to the various questions raised by the students and discuss the solutions with the learners themselves. Such an atmosphere of exploration should lead the learners to recognise a problem, define and analyse it, collect relevant data, process and interpret them, formulate a hypothesis and test its correctness and generality to draw a conclusion. An attitude of objectivity,

intellectual honesty and unbiased judgement should prevail during the process of investigation which can help the learners achieve a training in scientific method and attitude. They will be encouraged to be scientific in their thought and action in everyday life. This aspect of science learning, that is, the development of scientific method and scientific attitude, is more important and more valuable than mere acquisition of knowledge or facts of science. The students trained in scientific method are expected to solve problems in any situation they may come across. In this connection, Karl Pearson wanted to formally describe 'scientific method' in the following steps:

1. A problem is stated.
2. Observations relevant to the problem are collected.
3. An hypothesis consistent with the observations is formulated.
4. Predictions of other observable phenomena are deduced from the hypothesis.
5. Occurrence or non-occurrence of the predicted phenomena is observed.
6. The hypothesis is accepted, modified or rejected in accordance with the degree of fulfilment of the prediction.

The universality of such formal definition of scientific method has, however, been questioned by many educationists and authors. Keeslar suggested the following elements of scientific method suitable for high school students:

(*a*) Notice something that makes you think of a question that you would like to answer and make up your mind to try to find an answer to it.

(*b*) Decide exactly what the question or problem is and state it clearly in words.

(*c*) Study all the facts and see how they relate to the problem.

(*d*) Make as many possible answers to the problem as you can think of (making hypothesis).

(*e*) Select from these possible answers of hypothesis, the one you think is most likely to be the right one.

(*f*) Make up and carefully plan an experiment to find out whether the answer you selected is the right one.

(*g*) Carry out the experiment with great care according to the plan.

(*h*) Repeat the experiment to see whether you get the same results the second time. The second experiment is called check experiment.

(*i*) Draw your conclusion.

(*j*) Use the facts you have thus learned when you face a new problem similar or related to this one.

The above indicates the useful steps for exploring and solving a problem scientifically by students while at the same time the process inculcates in them a training in scientific method. An analysis of the various procedures followed by different scientists for solving problems in science, or an analysis of history of events in science, leads us to identify the following common logical steps involved in a scientific method:

(*a*) sensing a problem,
(*b*) definition and analysis of the problem,
(*c*) collection and organisation of relevant data,
(*d*) interpretation of data,
(*e*) formulation and selection of suitable hypothesis,
(*f*) testing or experimenting the hypothesis,
(*g*) drawing conclusions and generalisation, and
(*h*) application to new situations.

For school-level learners, problems of science may not be evident under ordinary situations. All the students may not possess equal degree of inquisitiveness of mind, enquiring attitude or environmental experience. At school stage, therefore, they need be to provided with situations which generate curiosity in them and lead them to question. Alternatively, the teacher may indicate the problem through a question or two. The topic, an item of their regular syllabus to be covered, should be presented in such a way as to be felt as something new and challenging and as a thing to be explored instead of it being repeated as a routine work to be taught every year to new batches of students.

Though many facts of science were discovered by chance, the majority of scientific achievements were the results of enquiry, effort and a deliberate desire to find. Science is a process of endless query and one question leads to another more fundamental question. But at school level, the learners need constant guidance and direction towards discovering a problem of science. The teacher has to lead his students to notice things that

provoke their thinking and raise questions in their minds. After discovering and ascertaining the problem, they should be able to define the problem in scientific language and proceed towards a solution: This sensing and defining of the problem serve the 'what' part of their question, while 'how' and 'why' parts are yet to be answered. For this, the learner will have to collect relevant data, analyse and interpret them and then formulate a number of hypotheses, select the most probable one among them and proceed to test the selected hypothesis through experiment.

After analysing the problem, the students need to plan the subsequent activities. They should discuss, consult references, use the needed audio-visual aids such as relevant pictures, charts, models, specimens, and do the experimentation carefully to test the validity or otherwise of their selected hypothesis. These activities demand their skill, abilities and reasoning power and on the other hand the whole process provides an opportunity to develop these abilities in them. The collected data need careful organisation, tabulation and involve accuracy of calculation. Unnecessary data needs to be discarded. The selection of appropriate hypothesis is a good test of their conceptual understanding and thinking power. After testing the hypothesis, they come to a conclusion and repeat the experimentation to verify the consistency and correctness of the conclusion arrived at. Repeatability is a good test of the quality of the collected data. The students should mark the limitations of conditions during their experimentation and include these limitations in their conclusions. When the same conclusions are arrived at in different sets of experimentation under similar situations, they may go for generalisation of their conclusion. The students should then be able to apply generalisations under new situations in their everyday life and be able to interpret similar events happening in their environment. In life situations, the students will come across circumstances that will demand application of their knowledge and ability to predict happenings.

As has already been mentioned, training in scientific method helps the learners solve many practical problems of life. But the habit of scientific enquiry or problem solving skill may not automatically be developed in those who may be interested to learn the contents only. The teachers will have to make

a deliberate effort to train the learners in scientific method while teaching them science. They must develop a proper attitude of mind to look into the practical problems of their life and their environment scientifically and follow scientific method to solve them.

C. The scientific attitude

A reference to the discussions in Chapter 2 will reveal that the development of scientific attitude of mind is one of the objectives of teaching science. It is a very significant outcome of the process of science education. Teaching of science should not only enable the learners to master the facts, concepts and principles of science or develop instrumental and problem-solving skills but also develop scientific attitude of mind as well as interest and appreciation in them. Scientific attitude of mind is essential to enable them to adjust themselves and live as efficient citizen in a scientific society. The National Science Teachers Association of USA says that as a result of science education, the learners should be in the "process of developing a personal philosophy based on truth, understanding and logic rather than one based on superstition, intuition or wishful thinking."

A scientific attitude can be developed only through personal experience and keen observation in the process of science learning. The teacher will have to provide situations in the classroom or field environment where the students can experience, see and feel the need for developing this attitude. For instance, open mindedness of the learners is necessary in scientific pursuits. They should respect others' opinion but at the same time believe only in verified facts. The spirit of enquiry must prevail in a scientific pursuit. They should learn to observe and think critically and accurately. Accuracy and precision are essential in scientific experimentation. The purpose of scientific pursuit is to find the truth. There is no place for bias or prejudice if truth is to be revealed. The student's observations, therefore, should be unbiased and objective. Intellectual honesty is indispensable in the study of science. While solving a problem, a scientist proceeds carefully and patiently, examines each step logically and holds back judgement until he is satisfied with the proof. These characteristics of any scientific pursuit should become a habit in the students learning science so that these are developed as a

mental attitude in them. The students of science must never believe in superstition or hearsay. They rely in cause and effect relationship and verified facts or proof.

In this connection, the *Rethinking Science Education* mentioned the characteristics of scientific attitude as "open mindedness, a desire for accurate knowledge, confidence in procedures for seeking knowledge and the expectation that the solution of the problem will come through the use of verified knowledge." These attributes of the mind are essential for solving a problem scientifically, be it a problem in the area of science or a social problem. It is true that the teacher will have to provide activities and situations where the students get an opportunity to develop scientific attitude. The learners may, in the process of studying science, miss these additional aspects involved in a scientific pursuit. The teacher should point them out to the students. Further, one textbook of science may not be successful in projecting various components of scientific attitude. The teacher should therefore encourage students to read different books on science because research studies have revealed that the students engaging themselves in wider reading inculcate scientific attitude more than those who read one textbook. But students should perform experiments or do projects in science themselves because without practical work in science, components of scientific attitude will remain unachieved by the students. Their personal experience is more valuable than verbal statements of scientific attitude. The development of scientific method and scientific attitude are constituents of the goals of general education and we must strive to attain them through the teachin of science subjects.

A discussion on the importance of honest doubt in science will be relevant here. It is sometimes seen that when a student doubts a statement of the teacher and puts questions to the teacher, he is usually silenced or even rebuked for not accepting the statement of the teacher. This practice is harmful; it thwarts the spirit of enquiry and honest doubt which, in fact, should be developed in the students. Moreover, this is not democratic teaching; it is authoritarianism. When the student is not convinced of some statement and hesitates to accept it, he is considered sceptical by the teacher and he discourages him. Such authoritarian teaching retards the development of critical thinking

and objective judgement, so important for scientific investigation. Such teaching imprints fixed ideas on the minds of the students. In science learning it is not wise to accept things blindly and without questioning if doubt arises. But unfortunately, in practice, it appears, the questioning student is often branded disobedient or aggressive. This is simply punishing original thinkers and rewarding unprotesting students.

There are many instances in the history of science where scepticism lead to great breakthroughs. Healthy criticism and a sceptical attitude are considered essential ingredients in science by many authors of science education, because without a questioning mind, science will lose its very foundation, that is, dynamism and progressive character. Philip Abelson in 'The need for scepticism' has pointed out (*Science*, 1962) that the great shortage in science now is not opportunity, manpower, money or laboratory space. What is really needed is more of the healthy scepticism which generates the key idea—the liberating concept." The teachers should always remember that without a questioning mind and a spirit of enquiry, studies in science will only mean acceptance of dogma and will never lead to development of scientific attitude in the learners. The students should not merely be supplied with information about science; they should be made to practice and observe science so that they get the opportunity to feel and develop the components of scientific attitude in their minds.

7

Curriculum and Content

> The intellectual content of religions have always finally adapted itself to scientific and social conditions after they have become clear . . . . For this reason I do not think that those who are concerned about the future of a religious attitude should trouble themselves about the conflict of science with traditional doctrines.
>
> —John Dewey

A. The meaning and concepts

The term curriculum is commonly understood to mean a course of studies, because the original Latin word (*currere*) meant a course run to reach a certain goal. The earlier accepted aim of education was also confined to the acquisition of knowledge only and, as such, curriculum was identified with the items of knowledge imported through instruction in the institutions. But the modern idea of education has undergone a revolutionary change and its aims are now much wider in concepts, meaning and functions. The modern world is a scientific world and the modern civilisation is a scientific civilisation. The modern scientific developments have made the world much smaller. Events in today's world are happening much faster and the society is also changing rapidly with time. In such a context, it is imperative that the concepts and meaning of education will change with the passage of time. Education is now considered a most dynamic social process and the concept of curriculum as a whole has also acquired a wider connotation.

The modern concept of curriculum is that it should cater for the all-round development of the learners. The Dictionary of Education defined curriculum a body of prescribed educative

experiences under school supervision, designed to provide an individual with the best possible training and experience to fit him for the society of which he is a part or to fit him for a trade or profession. In fact, according to the current concept, the curriculum includes the totality of experiences that the learners receive through all types of activities in and outside the classroom. The task of curriculum construction involves the selection of right experiences for the learners which will lead to the attainment of the educational objectives. It includes not only the course content, resources and materials for the purpose, but also the guidelines on the methods and approaches to the teaching of the subject. According to Cunningham, "curriculum is the tool in the hands of the artist to mould his material according to his ideals in his studio." Thus, curriculum is the instrument in the hands of the teacher, the artist to give shape to the materials, the students.

The traditional concept of equating curriculum with subject knowledge is no longer tenable. Science curriculum, as a constituent of the total educational curriculum, must contribute to the attainment of the objectives of education. As already mentioned, curriculum in the wider sense is over-all experience of the learners through a variety of activities pursued inside the classroom, in the laboratory, on the playground or through the formal and informal association with the teaching community. Such experience, duly guided, helps in developing and enriching the personality of the learner. And one of the major aims of education, as we all know, is the all-round development of the learners.

Curriculum evolves from life itself and, as such, curriculum planning should be life-centred. A curriculum must also conform to the needs of the state and the society. At the same time it should be flexible and dynamic since our modern society is fast changing with time. The curriculum should give more importance to the immediate needs of the individuals as well as the society and provide for their future needs too. We know that the psychological developments in a child are not abrupt but a continuous process. Therefore, whenever we are concerned with curriculum construction for any particular stage, we must see that it is continuous with the previous stage and is linked to the next stage. The young learners should be given continuous,

connected and sequential science experiences from the primary stage to the high or higher secondary stage of school education. Care should be taken in organising the course content so that the learners understand the basic scientific concepts, principles and definitions and see their application in everyday life. The methods and approaches for imparting science education should also develop in the learners the power of observation, critical thinking, and scientific attitude. The approaches should be inbuilt in the curriculum structure to lead the learners through instruction and experiences, to develop the right interest and appreciation, and also the skill and ability to apply their knowledge of science in everyday life situations. The science contents as well as the approaches should enable the learners to use their knowledge in solving their individual as well as social problems.

B. Construction of the curriculum in science

A curriculum should be flexible and broad-based to change according to the needs of the child and the society. Since the exposure a learner is subjected to, in or outside the school, ultimately has to benefit the society at large, curriculum should therefore be child-centred as well as community-centred. The learner has to live and move in a society and as such the curriculum must be related to his social environment. The curriculum on any subject should enable the learner to distinguish between right and wrong, good and bad. Thus, while preserving the best in his traditional and culture it must also enrich the cultural level of the society and the social environment. A well-planned curriculum helps the learner become socially adjusted in the society.

A curriculum is not just a list of theoretical statements. It must be activity-centred to be effective and interesting to the learners and must encourage creativity. It must satisfy the specific ability of each individual learner and lead him towards attainment of excellence in his skill. Science is a subject to be learnt by actually doing. There should be adequate provision in the curriculum for first hand experience through laboratory work or field-trips. A well-designed curriculum has a well-organised, well-graded, continuous, and practically attainable course content.

The science curriculum must conform to the aims of teaching

science, and must consider the age, stage as well as interest and abilities of the children for whom the curriculum is being framed. It should indicate the desirable behavioural changes expected of the learners as the final outcome of the curriculum. Each subsequent unit or item of knowledge must have link and relationship with the preceding unit or item of the contents. The contents should be organised in order of difficulty. But this does not mean that acquisition of knowledge is the only purpose of the curriculum. As already explained, the process aspect of science must be given equal, if not more, weightage than the product aspect. Without the development of the values of learning science, science education will not only fail in its purpose, but may also become detrimental. A good and well-planned curriculum should develop in the learners the power of thinking. It must also provide for the study of the contributions and sacrifices of the scientists of the world. The learners should be in a position to appreciate the sufferings of the great men of science while working for the benefit of the mankind. The curriculum must also provide opportunity for productive utilisation of leisure time of the learners and adequate locally relevant items of scientific activity to be pursued by the learners as hobbies.

C. The status of existing school science programme

The curriculum of school science has long been criticised by different bodies and commissions like Mudaliar Commission (1952-53) as well as Kothari Commission (1964-66). The Secondary Education Commission (Mudaliar Commission) criticised it for being narrow, bookish and theoretical, examination-oriented and unrelated to the child's environment. Remarking on the status of school curriculum in India in general, the Kothari Commission said:

> Against the background of the striking curricular developments that are taking place abroad, the school curriculum in India will be found to be very narrowly conceived and largely out of date. Education is a three-fold process of imparting knowledge, developing skills and inculcating proper interest, attitude and values. Our schools are mostly concerned with the first part of the process, the imparting of knowledge and

> carry out even this in an unsatisfactory way. The curriculum places a premium on bookish knowledge, making inadequate provision for practical activities and is dominated by examinations, external and internal. Moreover, as the development of useful skills and inculcation of right kind of interest, attitudes and values are not given sufficient emphasis, the curriculum becomes not only out of step with modern knowledge but also out of tune with life of the people. There is thus urgent need to raise, upgrade and improve the school curriculum.

Further, this Commission suggested introduction of the rural learner at secondary stage to the ideas and practices of scientific farming and the activities and skills related to it, while in the industrialised areas the curricula should have a bias towards the technical and industrial aspects of experimental science and its impact on industrialisation. But we are yet to go a long way in this direction. There are various reasons for which we find the subject-centred curriculum still persisting and science lessons being read and memorised even today. The Education Commission made valuable suggestions for the improvement of social science curriculum. The importance of the study of science for national development is well reflected in the National Policy on Education, Government of India (1968), wherein is specifically stated " . . . with a view to the national economy, science education and research should receive high priority. Science and mathematics should be an integral part of general education till the end of the school stage."

D. Selection and organisation of course content

Curriculum indicates the broad framework of learning experiences. The details of activity programme for actual classroom implementation in terms of attainable units is called a syllabus. A syllabus, therefore, gives the details of the course as prescribed in the curriculum to be learnt at a particular stage. It is not possible to have a course content valid for all times. A syllabus, like curriculum, is also serviceable for a certain duration of time. It has to be constantly reviewed and reorganised. Since there are many variable conditions in the teaching process, it is impossible for any syllabus to provide for the needs of all the

areas, all schools and all the pupils. Every school has its own scheme of work depending on the need of the area, quality of the staff, situation and type of school and the material and human resources available. Different schools may like to follow different methods of teaching to suit the existing circumstances. The pupils, too, vary in their age, ability and aptitude. So also, the teachers in their ability and the success of teaching different topics depend on their likes and dislikes. Moreover, it is one thing to have a course in detail for study and another to teach it successsfully. However carefully a syllabus is made, it cannot guarantee successful teaching, for it is not possible to evolve an ideal syllabus to suit all circumstances and serve for all times.

The selection and organisation of the science content is an important factor in determining the product of science learning. Usually, the teacher depends upon the textbook or the prescribed course of study for content-matter. Often, the textbook either contains extraneous matter or lacks in some vital up-to-date information. But even within the prescribed course content, the teacher will, to some degree, have to select and organise. The science content must not only serve the functional purpose but also inculcate the good outcomes of science learning. In the latter case, the content serves as a means to an end. The contents of facts, concepts and principles, in addition to being functional, should bring about behavioural changes in the learners.

The syllabus, in addition to the topics of content, should include experiments, demonstrations, as well as outdoor activities to be pursued. The content for elementary stage should be selected:

(*a*) in terms of the broad concepts and principles of science;
(*b*) in terms of the interests and the needs of the children;
(*c*) taking into consideration the age level of the children and the level of difficulty for the children.

The contents selected should be related to the local environment with which the children are familiar. The science course for children not yet mature should be elementary. The purpose at this stage should be to acquaint the children with the world around them. The science course should be confined to the study of nature such as plants, animals, common objects, simple natural phenomena, etc. It should also include an elementary knowledge

of personal hygiene, physiology and elementary study of soil.

The pupils of the middle stage undergo rapid growth and there appears an accelerated development of motor skill and ability. Their interests widen and the period marks the development of keen desire to explore, discover and excel. They are more interested in sports, teamwork and collection. They are curious about adventure and mystery. They desire some freedom too, but always feel the need for security. While selecting contents for the middle level, the above facts have to be kept in mind. The contents selected should:

(*a*) have use in their everyday life;
(*b*) lead to the inculcation of the desirable attitudes and outcomes;
(*c*) be appropriate to their level of ability;
(*d*) be in harmony with their needs and interests;
(*e*) encourage development of desirable social behaviour;
(*f*) contain matter from their familiar environment; and
(*g*) be continuous with the elementary science course.

At this level, elementary knowledge of physics and chemistry should be introduced. Important related topics should be selected from the biological sciences (botany and zoology), physical sciences (physics and chemistry), physiology and hygiene and domestic science (for girls). This course should serve those leaving school after the middle stage. There should be a provision for practical (individual or in groups) work and other group activities. Though the subjects and the course will be similar to the elementary level course, the method of approach and teaching will be different. More emphasis should be on activities. It should be remembered that the purpose and function of the middle level general science curriculum is to introduce the pupils to the broad fields of science. Thus, the general science curriculum for the middle level should be broad-based for familiarising the pupils with important fields of science. This is no stage for intensive study; neither it is a preliminary training for the high level science. The purpose here is to give some insight to the subject of science as a whole.

The adolescent stage is crucial. The understanding of the psychological developments in this stage is an important factor in planning appropriate curriculum for the High School level. This is also a period of rapid growth. Sexual maturity and a desire for

independence predominate this period. At this stage, their special abilities and interests take a definite form; they experience a period of intense specialised interests. The syllabus for the high stage should, therefore, be framed on the basis of these abilities and interests. The Secondary Education Commission has suggested wide variety of diversified courses for the pupils of high-stage (High and Higher Secondary schools). This, however, is meant for providing scope for development of special abilities and not for narrow specialisation. Since only a small percentage of the total student population go to university or other institutions of higher learning, and the majority have to think of earning a living after the secondary stage, "the educational programme should give them some training in this direction, not so much in terms of the specific vocations as in training their practical aptitudes in preparation for definite vocational work" (Report of the Secondary Education Commission).

Two types of science courses have been prescribed for the secondary grade pupils:

—a compulsory course of general science for all pupils imparted as a part of sound liberal education; and

—courses of special science subjects, which the pupils may choose according to their aptitudes and interests.

The topics for general science were selected from the following branches of science to form an integrated course: astronomy, physics, chemistry, biology, geology, physiology and hygiene.

The subjects prescribed for special science course were: physics, chemistry, biology, mathematics, geography, elements of physiology and hygiene (for those who do not offer biology).

It has been mentioned earlier that the contents of the above subjects arise from the vocational needs and the future career of the pupils. General science teaching has, however, a broader purpose in view. It forms a part of the general education of the pupils. While teaching general science, the procedure should be to introduce the subject through familiar things and pupils' own experiences. The illustrations should be from everyday life and local environment. The topics or the units of study in general science should be organised around the areas of pupils' experience. A judicious amount of practical work should follow theoretical teaching. Discussions about the lives of selected scientists make science learning more interesting and effective.

E. The teaching of general science

It has been explained in Chapter 1, that to live and survive in this modern scientific world, the knowledge and understanding of the basic aspects of science and a scientific outlook of mind is vitally necessary not only to the experts in science but also to the non-scientists and the ordinary men and women. Everyone should have at least the basic knowledge of facts, principles, concepts and information of science required for everyday living in a scientific society and to appreciate what scientists are doing for the welfare of the mankind and how science has influenced our everyday life. The necessity of general education in science as a part of liberal education was conceived by Plato long ago. He said that the origin of both literature and science was the same and that though they seemed to diverge in technical methods, they converge in purpose. He advocated teaching of science not for its own sake but to develop an attitude of mind which could enable learners to apply scientific method to social problems. He thus conceived science as a means to an end.

In society, learners who undergo school education need not become experts in science. Only a small percentage of students take up science as a profession, but all of them, whether they complete the school course or not, will have to live as a member of the society. Moreover, the majority of the school-going children are of average ability. Hence, every individual must be given a general education in science so that he is able to live intelligently in this technological world. Since science has become a part of contemporary culture, we must teach science to all citizens as part of general education to provide the learners with common interests, knowledge and skill for effective participation in the developmental activities in our democratic society.

The qualities and interests of the learners at the school stage are more or less common because of common geographical and social inheritance, common culture and common community life and a course of general science will benefit them all. John Murray says that the general science is a course of scientific study and investigation which has its root in the common experiences of children and which includes the fundamentals of special science. He also says, "It seeks to elucidate the general principles observable in nature without emphasising the traditional division

into specialised subject until such time as is warranted by the increasing complexity of the field of investigation by the developing unity of the separate parts of that field and by the intellectual progress of the pupils." The course in general science has advantages over special courses. Here science is taught as a correlated subject not only with the various branches of science but also with humanities.

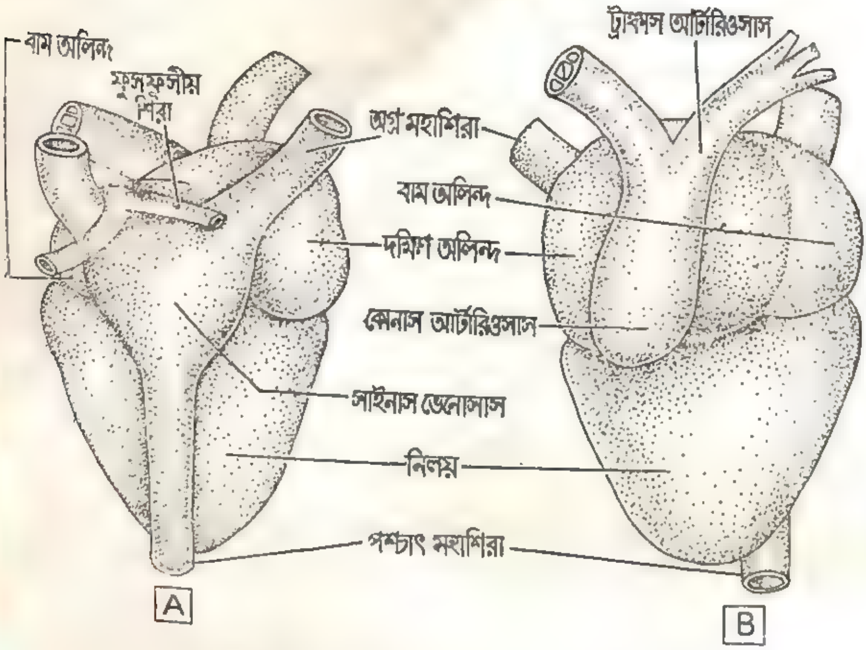
It, however, does not mean that the students with special talent in science will be neglected. There is provision to cater to the needs of the specialists. The State needs experts and specialists in science and technology. Though all the students cannot be expected to become specialists nor it is the function of the schools to prepare specialists, the school cannot shirk the responsibility of encouraging and nourishing the budding scientists. The school must motivate and help them learn and attain scientific abilities to the maximum of their potentialities.

The Indian Education Commission has recommended disciplinary approach to science learning rather than the general science approach. The Commission felt disciplinary approach would be more effective in providing the necessary scientific base to the young learners. It suggested teaching of science as physics, chemistry, biology, geology and astronomy from class five of the middle level (higher primary stage). The Commission disapproved the general science approach to the teaching of science.

The general science course mentioned above provides the basic grounding to the scientists as well as non-scientists. But the danger of over specialisation has not gone unnoticed. The Ministry of Education, England in its pamphlet No. 38 states:

> There are dangers inherent in the situation; we risk becoming a well-fed rabble ordered about by experts; subjects of a new despotism. We cannot do without specialists; if we are not to become their slaves we must see to it that scientific knowledge and the ability to reason scientifically are widespread. This does not mean that all must aim at becoming technical experts; that would be impossible and in any event, few can become experts in more than a limited field. What it suggests is that science must find a place in liberal education, without aim of turning every one into specialists, in the same way as language and literature have done without any thought of turning every one into authors or critics.

প্রকোষ্ঠ। একটি **সাইনাস ভেনোসাস** (Sinus venosus) ও একটি **কোনাস আর্টারিওসাস** (Conus arteriosus) হ'ল আনুষঙ্গিক প্রকোষ্ঠ।



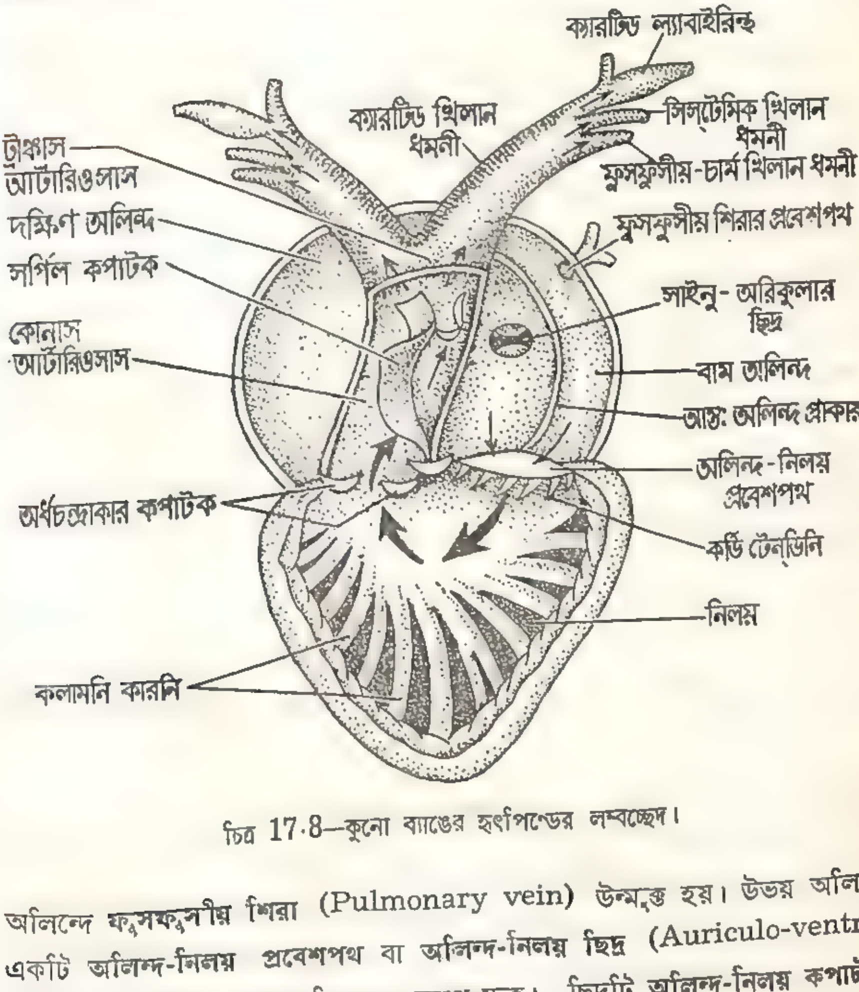
চিত্র 17·7—ব্যাঙের হৃৎপিণ্ডের বহিরাকৃতি ঃ
A—অঙ্কদৃশ্য ; B—পৃষ্ঠদৃশ্য।

সাইনাস ভেনোসাস (Sinus venosus) ঃ কুনো ব্যাঙের হৃৎপিণ্ডের পৃষ্ঠদেশে অবস্থিত ত্রিকোণাকার থলির মতো অংশটি সাইনাস ভেনোসাস। দু'টি **অগ্র মহাশিরা** (Pre caval veins) ও একটি **পশ্চাৎ মহাশিরা** (Post caval vein)-র মিলনে সাইনাস ভেনোসাস গঠিত হয়। সাইনাস ভেনোসাস প্রকৃতপক্ষে একটি **গ্রাহক প্রকোষ্ঠ** (Receiving chamber)। দুটি অগ্র মহাশিরা ও একটি পশ্চাৎ মহাশিরা মাধ্যমে কুনো ব্যাঙের সর্বাঙ্গ থেকে দূষিত রক্ত সাইনাস ভেনোসাসে আসে।

সাইনাস ভেনোসাস **সাইনু-অরিকুলার ছিদ্র** (Sinu-auricular aperture) দ্বারা দক্ষিণ অলিন্দের সঙ্গে যুক্ত। ছিদ্রটি **সাইনু-অরিকুলার কপাটক** (Sinu-auricular valve) দ্বারা নিয়ন্ত্রিত। এই ছিদ্রপথেই সাইনাস ভেনোসাস থেকে রক্ত দক্ষিণ অলিন্দে নেমে আসে।

অলিন্দ (Auricles) ঃ কুনো ব্যাঙের হৃৎপিণ্ডে অলিন্দের সংখ্যা দুই—একটি **দক্ষিণ অলিন্দ** (Right auricle) ও অন্যটি **বাম অলিন্দ** (Left

auricle)। দক্ষিণ অলিন্দটি অপেক্ষাকৃত বড়। অলিন্দ দুটি আন্তঃ অলিন্দ প্রাকার (Inter-auricular septum) দ্বারা সম্পূর্ণভাবে পৃথক থাকে। বাম



চিত্র 17·8—কুনো ব্যাঙের হৃৎপিণ্ডের লম্বচ্ছেদ।

অলিন্দে ফুসফুসীয় শিরা (Pulmonary vein) উন্মুক্ত হয়। উভয় অলিন্দ একটি অলিন্দ-নিলয় প্রবেশপথ বা অলিন্দ-নিলয় ছিদ্র (Auriculo-ventricular aperture) দ্বারা নিলয়ের সংগে যুক্ত। ছিদ্রটি অলিন্দ-নিলয় কপাটক (Auriculo-ventricular valve) দ্বারা নিয়ন্ত্রিত হয়। অলিন্দ দুটিও প্রকৃতপক্ষে হৃৎপিণ্ডের গ্রাহক প্রকোষ্ঠ।

নিলয় (Ventricle) : ত্রিকোণাকার ও পুরু পেশীবহুল নিলয়টি একটি অবিভক্ত প্রেরক প্রকোষ্ঠ (Forwarding chamber)। করোনারী সালকাস (Coronary sulcus) নামক একটি আড়াআড়ি ভাঁজ থাকার জন্য বাইরে থেকে অলিন্দ দুটিকে নিলয় থেকে পৃথক করা যায়। নিলয়ের মধ্যে নিলয়ের অন্তঃ-

The content materials for general science should be

(*a*) fundamental in nature;
(*b*) related to the local needs;
(*c*) related to the learners' environment;
(*d*) appropriate to the needs and interests of the learners;
(*e*) in harmony with the intellectual growth; and
(*f*) introduced through familiar experience.

After selection, the content materials are organised according to the correct procedure; because finally, it is the type of organisation that will decide the effectiveness of learning these materials. The forty-sixth Yearbook of the National Society for Study of Education (USA) gives the following guiding principles for organising the science contents:

1. Contents should be organised into large areas or units, each representing a major problem of living, area of human experience or aspect of environment.

2. The content of any single area or unit should be split into smaller learning problems which have interest, significance and usefulness to the learner.

3. The learning experience in any single problem should be organised to promote functional understandings, growth in instructional skills, growth in the processes of problem-solving, and the development of attitudes, appreciations and interests.

4. Abundant opportunities should be provided for applying and building concepts and principles.

5. Provision should be made for effective evaluation including self-evaluation.

6. The sequence of units should be planned to give recurrent contacts with facts, concepts and principles of science and provide a spiralling and enlarging pattern of growth in concepts and principles.

7. Problem situation should provide definite training in one or more of the elements of scientific method.

8. The course in science should be original and provide frequent opportunity for pupils to participate in planning and engage in individual and group projects.

The arrangement of the content matter may be made either in order of discovery, according to some logical order, or

grouping a round some central theme such as a general principle in science or a local scientific phenomenon. But while doing so, there are other factors to be taken into account such as the teaching facilities in the school, type of the teaching staff, etc. There are a wide variety of items in general science which can be arranged in either of the ways mentioned above. For example, a number of topics may be organised around the idea of 'gravity'; similarly, a large number of lessons can be established around a local 'hydroelectric project'. In the study of chemistry, lessons on 'element' should precede the lessons on 'compound'. This is quite logical. Any topic may be developed by following different stages through which it has undergone changes and developments since its early beginnings. A study about 'atoms' can be started with the ancient idea of the Greeks, and followed with the idea of Dalton, Bohr and others up to the modern concept about the atom. This is an example of arrangement according to the historic order or the order of discovery.

The Unesco handbook on "Teaching of Science in Tropical Primary Schools" suggested organisation of the subject-matter of elementary science around the three broad areas—the earth and the universe and matter and energy. The all-India seminar on the teaching of science in secondary schools suggested organisation of the contents of science under environment-centred topics, life-centred topics, and environment and life-centred topics, to bring about integration among the various branches of science.

(a) Environment-centred topics

Unit—I The atmosphere
—II Water, a vital need of life
—III The earth's surface
—IV Fire and heat
—V Effect of heating and cooling on air and water
—VI Study of light
—VII Civilisation and use of metals
—VIII Work and energy
—IX Problems of transport and communication
—X Plants and animals in relation to life
—XI The study of body machine

—XII Understanding ourselves
—XIII Science and philosophy of life, time-chart and case-histories.

(*b*) *Life-centred topics*

Unit—I The world that science has built
—II The air we breathe
—III The water we use
—IV The food we eat
—V How man gets his food
—VI The clothes we wear
—VII The houses we live in
—VIII The machines we use
—IX The power we work with
—X Protection from diseases
—XI Our biological resources
—XII Our mineral resources
—XIII Means of transport
—XIV How we communicate with the world
—XV The universe we live in
—XVI Story of life
—XVII How to be yourself.

(*c*) *Environment and life-centred topics*

Unit—I The world that science has built
—II The body machine and how it works
—III Health to you
—IV Using biological resources for better living
—V Using mineral resources for better living
—VI Energy and machine for the world of tomorrow
—VII Time, measurement and mass production
—VIII The weather and what we can do about it
—IX Astronomy— (*i*) Solar system in which we live
(*ii*) Stars and other universes
—X Science for our houses
(*i*) Heating homes, (*iii*) Lighting houses, (*iii*) Electronics in the home, (*iv*) Sound in ,the home, (*v*) Science and people.

The general science syllabus for the classes one to eight,

published by the NCERT in 1963 developed the units of study around the following broad areas of contents (through major and minor concepts):

(1) Air, water and weather; (2) rocks, soils and minerals; (3) human body, health and hygiene; (4) safety and first-aid; (5) housing and clothing; (6) energy and work; (7) matter and materials; (8) living things; (9) plant life; (10) animal life; (11) scientists at work: and (12) measurement.

The major and minor concepts are related to facts and events of everyday life and include necessary practical work as well as outdoor activities.

The Board of Secondary Education, Assam, prepared the general science syllabus for classes five to ten, covering the entire secondary course in nine major concepts and 441 minor concepts.

The Education Commission 1964-66 (Kothari Commission) has also examined in detail the different aspects of science education at the school as well as higher education stages. The Commission recommended that:

> In the lower primary classes, the focus should be on the child's environment, social, physical and biological. In classes I and II, the accent should be on cleanliness, formation of healthy habits and development of the power of observation. These should be emphasized again in classes III and IV, but the study should include personal hygiene and sanitation. The child may also be introduced to formal areas of science such as the plants and animals in his surroundings, the air he breathes, the water he drinks, the weather that affects his daily life, the earth he lives on, the simple machines that are being used in his environment, the body of which he should take care and the heavenly bodies he looks on at night. School gardening is an activity that should be encouraged especially at this stage, as it provides pupils with direct and valuable experiences of natural phenomena.
>
> We also recommend that in class IV, children should be taught the Roman alphabet. This is essential as the internationally accepted symbols for the units of scientific measurement and symbols for chemical elements and compounds are written in the Roman alphabet. Whatever one's language and the word for water, the chemical symbols for it is always H_2O. And it is far more than a symbol, it

provides an insight about the nature of water. Again, a knowledge of the Roman alphabet makes possible the use of maps, charts and statistical tables on an international scale. How expensive and time-consuming it will be to make available this material in all the local languages.

At the higher primary stage, the emphasis may shift to the acquisition of knowledge together with the ability to think logically, to draw conclusions and to make decisions at a higher level. Science should now be taught as physics, chemistry, biology, geology, and astronomy. The allocation of these subjects among the three classes is suggested below; but other combinations may be tried depending upon the level of the students and local conditions:

Class V—physics, geology, biology;

Class VI—physics, biology, chemistry;

Class VII—physics, biology, chemistry, astronomy.

The general science approach to the teaching of science which has been widely adopted at the elementary stage during the last ten years has not proved successful as it tends to make science appear somewhat formless and without structure and runs counter to its methodology. A disciplinary approach to science learning would. . . be more effective in providing the necessary scientific base to young people. The introduction of astronomy is specially commended, as it plays an important part in imparting good science education and in developing a rational outlook. From class V onwards the Indian almanac should be studied by observations of the night sky.

Every primary school should have a science corner or a room to keep specimens, models and charts with the necessary storage facilities. A minimum of one laboratory-cum-lecture room should be provided in every higher prim y school.

Science in the Secondry School: At the secondary level, science as a discipline of the mind and a preparation for higher education deserves special emphasis. In the lower secondary classes physics, chemistry, biology and earth sciences should be taught as compulsory subjects for all the pupils. Building on the introductory courses at the earlier stage, they should be made to cover wider areas and go deeper into the content than before. The changing character of the sciences should be the major factor in curriculum development.

Features of the Secondary School science curriculum: During the last few decades, the conceptual framework of physics

has undergone a drastic change and this should be reflected in the high school physics curriculum. Similarly, in chemistry, the stress hitherto laid on memorization of facts, formulae, processes and compounds should give place to an emphasis on the unifying concepts in the subject. It is necessary to highlight the applications of chemistry in industry and daily life and its growing importance in our developing economy. Again, the present content of the school course in biology is traditional in nature. The concept of biology as a method of inquiry by means of accurate and comfirmable observations, quantitatively and mathematically analysed, and controlled experimentation should be impressed on the minds of the young learners. Earth sciences should be introduced in the secondary school, geology and geography being taught as an integrated subject. There are also many areas in chemistry, physics and biology to which certain topics in the study of earth sciences can be naturally related.

F. Curriculum development and science education

It has been pointed out earlier that the curriculum reconstruction is a dynamic process. Even a well-designed, well-thought out curriculum cannot continue to be applicable for all times. This is specially true in case of science education.

The growth and development of science in this modern world has been so rapid that it has become difficult for mankind to cope with the changes. The scientific knowledge doubles itself every decade. The concepts or facts of today may become out-of-date tomorrow. The curriculum, and hence the syllabus, must undergo constant research and review. The curricula are becoming outmoded and inadequate more quickly in the recent times. This appears to be a world-wide phenomenon. As the Indian Education Commission stated that the school curriculum is in a state of flux all over the world today. Even in the most advanced country like the USA the reformed current curriculum is also being criticised and challenged. The recent trend in reforming curriculum development has been to shift emphasis of school science education from knowledge aspect to "interpretation and process" aspect. The Physical Science Study committee (PSSC) for physics, the Chemical Education National Study Committee (Chem Study) and Chemical Bond Approach Group (CBA), for chemistry and the Biological Sciences Study Committee (BSCS) for biology teaching were the study groups in the USA which

during 1956 to 1960 studied curriculum improvement of secondary science programmes. Similarly, in the United Kingdom, Nuffield Foundation undertook projects for preparing improved curricula in physics, chemistry and biology. In India, the Indian Education Commission of 1964-66 recommended a number of steps for improving science education in this country.

In this connection, a special reference ought to be made to the remark of the Commission that while science must be pursued with full vigour to achieve Indian renaissance, the development of science must draw on the cultural and spiritual heritage of India. It disapproves following the western pattern, and suggests that the improvement programmes in science education should be based on the indigenous thinking reflecting "Indian ethos and value judgement." Since the imbalance between the growth of science and the attitude of welfare for mankind has engaged the attention of the western thinkers, the Commission has rightly pointed out that "knowledge and wisdom, power and compassion, are out of balance." Hence, curriculum planners ought to note the warning seriously for future guidance.

8

Science Learning at Different Stages

The only true teacher is he who can convert himself as it were to a thousand persons at a moment's notice; who can immediately come down to the level of the student and transfer his soul to the student's soul and see through the student's eyes and hear through his ears and understand through his mind.

—Swami Vivekananda

A. Principles of science learning

An important prerequisite in science learning is motivation. Without interest and incentive learning does not become meaningful. Motivation may therefore be said to be the heart of the learning process. The teacher should introduce the topic of science in an interesting way and make the content presented meaningful so that the learners find their work interesting and do all the activities willingly. It is the responsibility of the science teacher to evolve new patterns in his teaching to motivate the pupils to learn with zeal and eagerness. He should make use of incentives such as: providing scope to display pupils' work; providing opportunity to do independent work; giving responsibility and leadership in scientific activities; keeping the pupils informed of their progress in science; providing opportunity for pupils' demonstration; arranging for pupils' cooperative enterprise in science; organising field trips or visits and also science clubs and science fairs; creating a sense of healthy competition among the pupils. The learners should be actively involved in the learning experience. But in science, many concepts such as atoms, molecules, energy, etc. are

beyond the direct experience of pupils. Models and other audio-visual aids should be used to explain these concepts or principles.

The physiological factors are no less important. Knowledge is gained through sense perceptions and therefore learning depends on the conditions of the senses of the pupils. Defect of any one of the senses, such as defect of sight, defect in hearing retards learning. Since conditions of the body affect the state of the mind, learning depends on the general health. A good health is therefore necessary for learning; this is more true in the case of learning science.

Another important factor is the environmental conditions, such as atmospheric conditions, surrounding conditions of the school or the classroom, the physical conditions (arrangement) inside the classroom which determine the effectiveness of learning. Those who have experience of teaching in the hot, sultry days of summer or in a room nearest to the main road or a railway-station, bus stand or a toilet, can well realise this. The science teacher can, at least, arrange the things in the classroom to create an environment congenial to learning science. The pupils should feel that they are in a scientific environment.

The teachers should be familiar with the psychological principles of learning—the law of readiness, the law of exercise. The effect of motivation and incentive have been discussed earlier; these are connected with these laws. Another important consideration which the science teacher should know is that different pupils learn through different ways. Some pupils learn more by reading, some pupils learn through actual handling and manipulation; others learn better through audio-visual aids and still others learn well through demonstrations. The science teacher is fortunate in this respect, because he can use a variety of resources or arrange a variety of activities for science teaching. Plenty of charts, diagrams, graphs, maps or films are available for science teaching. It is also possible to find suitable places for field-trips or visits. The availability of reference books, journals, pamphlets or illustrated booklets in regional languages varies from state to state. But such material is easily available in the English language. Demonstration may be given with the help of simple or improvised apparatus. The science teacher should resort to these avenues for teaching science, according

to the circumstances.

Some pupils have a fascination for certain parts of the subject or topics in a particular branch of science. The teacher, while providing opportunities for those with special inclination, must persuade and convince them to take equal interest in other branches of science also. More important than this is the difference in learning. Individuals differ in their needs and abilities. The science teacher should see that as far as possible the individual needs are met. He should provide for additional activities or arrange extra curricular activities for individual progress in the areas of special interest.

B. How pupils learn science

(i) Science learning at the primary stage

The pupils at this stage are inquisitive and curious to know the things around them. They ask questions about the hows and why's of things and events that occur in their environment. They are fond of playing and always keen to do something. This is a period of rapid growth; they possess energy and are always restless. They like to spend more time with friends and take special interest in nature. They take pleasure in constructing things with simple tools and ordinary materials. They have a fascination for stories, fairy-tales or interesting life-stories; they are very imaginative. Brightness, sound, colour, animals or other natural phenomena immediately attract their attention.

The science teacher should take advantage of these natural abilities of the pupils and provide them with suitable experiences through doing something. This is the best stage to whet their interest in science. Care must be taken while providing experiences to teach them simple concepts of science; because once a concept is wrongly conceived, it is very difficult to correct it at a later stage. It, however, cannot be expected that pupils of this stage will be able to understand the abstract ideas of science, or the various applications of science. But they can be trained to observe and develop physical skills.

Pupils should be taken out for first-hand experience with nature. They may be taken to the woods, river-side or lake-side, botanical garden, zoo, or public parks. They may be taken to

a poultry-farm, fish-farm or an agricultural farm for first-hand experience there. In case of urban areas, the pupils should get the opportunity to experience the varied life of a modern community such as visiting a post office, a railway station, a seaport, or an air-port and see the working there. Each school should possess an aquarium, a vivarium and a garden. Gardening can be very useful in giving the pupils knowledge of various facts and phenomena of nature. By working in the school garden, the pupils become familiar with the names of various vegetable and flowering plants, the process of manuring and of plant growth. Through gardening, they may be taught simple arithmetic and made familiar with simple plane geometrical figures; the different plots growing different types of plants may be made triangular, square, rectangular or polygonal in shape. Moreover, working in the school garden satisfies their desire for doing something and develops a sense of dignity of labour and a sense of co-operation. Manual labour is good for their health. The school should also have a science museum where the pupils can preserve their collections.

The teacher should encourage them to collect interesting specimens to be preserved or displayed in the classroom. This satisfies their instinct of acquisitiveness. If the school possesses a small zoo, the pupils feel the school as the most interesting place. The science teacher can utilise the zoo for imparting to the pupils the knowledge of animal habits, their behaviour and their relation to man. Interesting activities suitable for the primary level pupils are constructing bird-houses, keeping weather records, scrap-books or diaries, collecting various types of stones, seeds, fruits, leaves, insects, butterflies, wild flowers, photographs or sketches of scientists, exploring fields and woods, rearing toads, frogs, insects, birds, rabbits, pigeons in the school, making models of cars aeroplanes with cheap materials, experimenting with magnets, torch-cells, electric bells. The teacher should also collect interesting illustrated elementary books of science experiments, or biographies of scientists written in their mother-tongue, for the pupils and suggest them to read. He should also try to develop healthy personal and social habits. It is the time for moulding the pupils and to inculcate the good habits and attiudes. They should be provided with situations to apply and practise these good habits.

(ii) Science learning at the middle school stage

Growth is a continuous process without sharply defined stages. One stage merges with the other through slow and continuous change. Therefore, the teaching at this stage should be linked with the primary stage; but, because of change in interest and expansion of experiences at this stage, the teaching of science should, however, take some definite form. It is essential that at this stage, marked for increase in physical strength and extreme gregariousness, appropriate activities be provided. Group activity is most suitable at this stage to satisfy their muscular ability and group loyalty. They also begin to take interest in the people of the community and other affairs of the society. The science teacher should plan activities through which the pupils may feel the importance of science for the society. They become critical of everything around them and always want reasons or causes for things or events. They take extreme delight in adventure. Outdoor learning activities should be planned to exploit their natural liking for the purpose of teaching. Field trips, picnics or visits to places of scientific interest are very useful. The teacher must always be with them during outdoor activities to help and guide them and to answer their questions.

At this stage the pupils seem to be impatient to do things that interest them, but are careless in some of their habits and actions. The science teacher should therefore plan activities of interest to the pupils and also arrange suitable activities which demand exactness, care and precaution. Often, the pupils display their individual skills and therefore it is advisable to provide for individual experiments, too, in addition to the group activity. The pupils may be made to work in the school garden in a group, but each individual may be made responsible for care and development of a particular aspect. At this stage, too, the pupils possess strong desire for collection. The teacher should encourage them to collect materials that interest them. The pupils may be asked to classify their collections and keep them in the appropriate place. They also show keen interest in reading. The science teacher should select appropriate books on elementary science for them to read. This stage is most suitable for training them in necessary mental and physical skills.

(iii) Science learning at the secondary stage

This is a stage in which the pupils undergo rapid physiological changes. Psychologically, this is a stage of storms and stresses; they often appear moody and imaginative. Their intelligence grows fast and their power of understanding takes shape. As a result of attaining intellectual maturity and language ability, they are in a position to comprehend abstract facts. They grow an attitude of independence and develop a strong feeling of self-prestige. Their specialised interests are well defined. They develop a logical mind and can reason. They like to solve challenging problems.

The science teacher should try to exploit the adolescent characteristics for the purpose of teaching science. He should throw challenging problems from the field of science and ask them to solve them. This stage is most appropriate for training them in scientific method, careful observation and unbiased judgement. Training in method is an important objective of teaching science in schools. The pupils should be given work in the special fields of their interest. The teacher should also arrange activities to acquaint pupils with the methods and procedures which the scientists follow to explore and exploit nature for our use.

The pupils should be so engaged in scientific activities, that they may realise the impact of science on the modern society. They should be encouraged to investigate scientific problems individually or in groups. They should be placed in situations where they can generalise and deduce. Their thirst for undertaking responsibility can be met by engaging them in work of projects, science club, science fair, etc. They should be encouraged to take active part in arranging science exhibitions, discussions, or debates on scientific topics, field trips or visits to places of scientific interest. Such experiences in the field of science enable them to learn science through activities appropriate to their age and ability. Due to maturity in skills, many pupils of this stage are keen to repair science apparatus and equipment or to improve apparatus. They should be given an opportunity to do so. The teacher's attitude towards them is an important factor which determines his ability to control these senior pupils. The teacher should work with them in the laboratory or in outdoor activities or engage some of the pupils to

perform simple demonstrations before the class. Special talents in science should be given facility and guidance to flourish in the field of their interest.

Here the science teacher is in an advantageous position for the fact that the adolescents develop the characteristics of volunteering for individual responsibility. But at the same time they like to work with their friends. They begin to develop a liking for publicity of their success. The teacher should remember that the adolescents like freedom in their actions and resent interference. They like manipulative work and want to do something new by themselves. They eagerly accept project-work and their participation can be profitably used for repair work and improvisation of apparatus and other simple scientific appliances.

9

Resources and Materials for Teaching Science

Great discoveries and improvements invariably involve the cooperation of many minds. I may be given credit for having blazed the trail but when I look at the subsequent developments I feel the credit is due to others rather than to myself.

—Alexander Graham Bell

A. Science textbooks

We acquire knowledge in two ways: through our direct experiences and by learning from others' experiences. A book belongs to the latter type of learning source. A textbook contains material chosen according to a plan and with a specific purpose. Traditionally, a textbook has been an unavoidable instrument in any teaching-learning process. No doubt, reading is an important means of communication. Next to the teacher's oral presentation, the textbook is the most widely used teaching instrument. The textbook is considered almost synonymous with schooling. It is the most influential factor in determining the content and the approach of teaching. In fact, most of our science teachers will be at a loss without a textbook. A teacher entering the teaching profession cannot be expected to select science content and determine the approach like an experienced teacher. It will be advisable for him to take the help of a good textbook to guide him. A textbook helps him in teaching systematically. Textbooks will probably continue to be used both by inexperienced as well as the experienced teachers at all levels of instruction.

Many educationists disapprove of the use of textbooks because of their misuse and over-use. Most of the science teachers become almost completely dependent on the textbooks and take the textbook as the only source of information. Over-dependence on the textbook limits the advantages of its use. The textbook should never be allowed to dominate the science-teaching programme. A textbook is one of the many devices available to him for teaching science. The textbook is a means to an end and not an end by itself. The textbooks, note-books, reference books, laboratory experiences, charts, diagrams, films and the many other teaching aids—all contribute to the learning of science to varying degrees. A well-balanced programme, utilising all these resources, can only give the best result. Each type of the teaching device has its own merits and a well-balanced combined use of all gives the pupils advantages of each.

A textbook is considered to be a course of study organised according to a set plan and a learning-guide rather than a source-book of information. A textbook, however carefully prepared, cannot be perfect and it is impossible to incorporate all the aspects demanded. Moreover, a textbook is apt to get out-ot-date if not revised regularly. This fact is specially true in case of a science textbook, because scientific knowledge and its applications to our life are increasing everyday. To prepare a textbook, truly suitable for a particular grade of pupils, is a difficult task. Textbooks are usually meant for the average pupils. A class in practice consists of pupils with varying abilities. Individual pupils vary in their liking for a textbook; so also the teachers. Textbooks prepared by different authors on the same subject for pupils of the same age and background, often differ considerably in content and quality. One author may give importance to one type of knowledge than the other, whereas the other may do quite the opposite. One textbook may be successful in exposing certain topics, whereas another textbook may vitalize some other topics. Two textbooks written by two different authors following the same principles and with the same ideas in mind, may also differ in several aspects. Therefore, the needs of a class can never be fully met by textbooks. Moreover, some textbooks contain unnecessary information and others omit some important topics.

Textbooks are usually general and comprehensive in nature.

The details of any topic and relevant local examples may be lacking. Hardly any textbook discusses the exceptions and limitations of the facts and principles. Also, it may not be possible to refer to all the local examples which vary from area to area. This is because the textbook has to be general in nature and is written on a state-wide or country-wide basis. Therefore, it is left to the teacher who teaches science, to mention the relevant examples available in the local area. Most of the textbooks do not provide useful, practical problems of our daily life, graded according to the level of difficulty. A textbook without unsolved problems appropriate to the grade, cannot inculcate the skill of problem solving in the pupils. A textbook which satisfies the needs of the retarded as well as the advanced pupils is difficult to get. The Secondary Education Commission reports that most of the books are poor specimens—"the paper is usually bad, the printing is unsatisfactory, the illustrations are poor and there are numerous printing mistakes." Even the lay-out and design of our textbooks are poor. The language and the manner of presentation are usually unsatisfactory; factual mistakes are also frequent. A bad textbook is detrimental to the effective learning of science. It is better not to have any textbook rather than a bad one.

Since a good textbook provides not only the contents of science but also determines the method of teaching, a textbook therefore occupies an important place in the classroom situation. Hence, the science teacher should be familiar with the purpose and function of a textbook and the principle of selecting a good textbook. A good textbook saves a teacher much time and energy in preparing his daily lesson. It stimulates thinking in the minds of the learners besides supplying necessary information of science. One of the important purposes of using a textbook is to enable the pupils to gain the power of understanding and interpreting facts and ideas presented in the book. A textbook should help self-education. It should also indirectly cultivate the reading habit. The science teacher has an important obligation—he must enable the pupils to realise that the textbook is neither the only source of information nor the ultimate source of authority. A textbook is necessary to supplement classwork and for home study by the pupils after the topic is done in the school. It helps the pupils to prepare assignments and in

revision of the course. It is true that neither the textbook nor the teacher alone can be the best medium of instruction; but a good textbook and an experienced (trained) teacher can make the teaching-learning process effective.

B. Selecting a textbook

1. Contents: The contents selected should be appropriate for the age-level of the pupils and should conform to the syllabus prescribed for the particular grade. It should be up-to-date and should be related to the everyday life and experience of the pupils. The concepts desired to be imparted should not be too difficult for the majority of the pupils. The contents selected should be consistent with pupils' needs, interests and previous background. The statements of facts and principles must be correct. In addition to containing the known, the content should also reflect the unknown, and the uncertainties in science. The topic should be illustrated with diagrams, pictures and charts. Local examples should be included. The major headings and the subheadings should be appropriate to the content. The diagrams and illustrations used should be as simple and conspicuous as possible.

2. Organisation: The subject-matter should be organised in a psychological sequence with the content-material presented in such a way as to make the subject meaningful to the pupils for whom it is designed. A textbook should not contain lessons of mere narrative type; a good textbook should present the content through topics of interest to the pupils. A discussion on any topic in the book should not merely raise a problem and give the solution; it should lead the pupils to experimentation—individually or collectively—and observation, and also suggest projects or supplementary readings. It is necessary, while organising the content matter of science, to consider the seasonal changes. For example, the study of a frog or a rainbow should be undertaken in the rainy season. A sufficient number of more difficult problems and projects should be provided for the more advanced pupils.

3. Language: The language in a science textbook should be easy and within the comprehension of the pupils for whom the book is written. The sentences—short, simple and correct—should be unambiguous and clear in expression. Science terms should

be introduced only after defining them clearly. A vernacular word used for a scientific term should have the English equivalent within brackets.

4. Physical aspects: The get-up of the book should be attractive. Print and paper should be of a good quality. Illustrations and diagrams should be bold, distinct and attractive. The size of the book should be proportional—not too large (bulky and thick) nor too small or narrow. The cover design should be appealing. The get-up of the book has psychological implications. The first look at the textbook creates an impression on the minds of the pupils which determines their desire to handle and study it.

5. General points: The textbook should usually be accompanied by a laboratory manual. A good textbook should mention the teaching aids and other supplementary reading materials too. Each chapter should begin with a short introduction and end with a summary of the chapter. The problems and numerical examples should be graded according to difficulty. It should contain a new type test in science. This, however, presupposes teachers' knowledge about the new type objective tests. In general, the book should be written in such a way that its study creates interest in science, develops the sense of appreciation and power of thinking, reasoning, observation and judgement. Besides giving the readers factual knowledge, it should help them develop technical skill, scientific attitude and train them in the scientific method.

C. Reference materials

Pupils should have access to a sufficient number of books in the school library. Reference books are used to supplement knowledge gained in the classroom and also to acquire new knowledge. Such reference materials may consists of books, pamphlets, magazines, newspapers or illustrated journals and other periodicals. Consulting reference materials in connection with the classroom topics should not only be encouraged but should be considered an integral part of the teaching-learning process.

In addition to the general encyclopaedias, childrens science encyclopaedias appropriate for different grades of pupils, reference books in general science and others dealing with

particular fields of science and illustrated science journals should be available in the school library. The reference books should satisfy the needs of the average pupils and also the backward pupils. Thus, reference books in addition to serving as a supplementary reading should serve as a means of self-improvement. But the effective use of reference materials depends upon the teacher. He should be familiar with these materials in advance and guide the pupils in deriving the maximum benefit from the reference materials.

D. Science library

There should be a separate library for science books located in the science room. One corner of the classroom can be conveniently used for housing the science library. It should contain different types of textbooks, varieties of reference books and all other associated reading materials such as pamphlets and illustrated scientific journals. The books should cover all branches of science such as astronomy, physics, chemistry, biology, geology, physiology, nature-study, etc. There should be books on romance of science, history of scientific discoveries and inventions, agriculture, engineering and also books on the life and works of great scientists.

Therefore, in addition to the vatieties of textbooks, the science library should contain the following types of books:

1. Inspirational books, which inspire the readers and create interest in them for studying science.
2. Background books, which are the essential knowledge books on various topics.
3. Reference books of varied coverage.
4. Science magazines and journals.

The teacher should be able to select suitable science books for the library as there are many books on science available in the market. It is unfortunate that there are very few books of these types written in regional languages.

Such a science library is unavoidable when the teacher desires to follow the reference-book method of teaching science. The science library should contain science books of advanced standard in order to enable the talented pupils to explore the new areas of science as rapidly as their abilities permit. Though

a science library may not benefit all the pupils, but they will feel that reading is a pleasurable activity.

E. Apparatus and materials

Psychologists have found that 'learning by doing'—the most effective method for learning science—has many advantages over other methods, such as reading about principles and concepts of science and their application, and observing others doing experiments. Experiments by pupils inside or outside the laboratory are first hand experiences. It is obvious that to live in this modern scientific world efficiently, first hand contact with the apparatus and materials of science is essential. Demonstrations also provide some direct experiences but not as effective as individual experimentation; because in a demonstration the teacher takes the leading part, whereas in an individual experimentation, each pupil gets an opportunity to handle and use apparatus and materials of science.

A modern school science programme cannot be conceived without practical experimentation by the pupils whose practical work in connection with the theoretical discussions of a topic should be considered an integral part of the science programme. We know that science is essentially a practical subject and that the young pupils always like doing something rather than listening or observing. Hence, practical experimentation of the principles or of the applications of science by the pupils can enable them to understand science properly. There are many facts and principles of science which are difficult for the pupils to believe or appreciate unless they themselves do the ex ri- ments and find the truth. To cite a simple example, the for, a- tion of an inverted image of an object on the other side of a convex lens cannot be appreciated easily. The pupils remain wondering until they see that the image really appears on the other side of the lens. The pupils should be given the opportunity to find the truth themselves. It may not, however, be possible to arrange experiments to find the truth of all the principles they ought to learn.

The terms, principles, their applications and the materials of science become more meaningful by actual use. Hence the need for practical work in science. Many important principles, laws and generalisations of science will remain abstract to the

pupils without practical demonstration or individual experimentation. They will simply learn to memorise them without understanding. Practical work thus makes science meaningful.

A long talk, however interesting it may be, becomes boring for the young pupils. They do not have the patience to listen or pay attention to a particular activity for a long time. They need diversion. Practical work in science provides for this. The use of apparatus and materials for performing a demonstration experiment or doing individual and group practical work breaks the monotony of classroom teaching, introduces variety and provides motivation for learning science. A dramatic situation may be created in the classroom or in the laboratory by performing an interesting demonstration using scientific apparatus and materials. Many lessons can be made effective by starting the lesson with an interesting demonstration. A well-planned use of the apparatus and materials of science can never make the science class dull.

It is psychologically sound to provide for individual differences. One of the important advantages of using apparatus and materials is that there are possibilities for providing for individual needs and interests. All pupils are not equally benefited from reading books or attending class teaching. Some pupils have inborn abilities for handling scientific gadgets and doing experiments. The availability of apparatus and equipment provides them scope to exhibit their merit. It is a common experience that many pupils like to make radios, cameras, and simple machines. This attitude is strengthened when they see apparatus and equipment in the science room or the teacher demonstrating with apparatus or while the pupils themselves do experiments. Thus apparatus and equipment contribute to the development of talent.

Apparatus and equipment are necessary to train the pupils in scientific method. It is through the use of apparatus and materials that we can train the pupils in accurate observation, collecting data or evidence, analysing the data, making hypothesis and testing it, selecting useful and consistent evidences and drawing a conclusion. Setting up an experiment for a problem at hand or even sensing a problem, taking necessary precautions and care, and developing manipulative skill in handling apparatus and materials are possible only through

actual use of apparatus and materials. To develop critical thinking or scientific thinking, experimentation with apparatus and materials is necessary.

Performing experiments with the help of apparatus and materials at the school stage will help the future scientists to investigate difficult problems in their later career and enable them to undertake original work independently. Another purpose for which the use of apparatus and materials is advised is to provide an environment to pupils for exhibiting initiative, resourcefulness and co-operation. These qualities enrich their personality. Field trips, pupils' projects also give an opportunity to develop these qualities. But doing experiments using apparatus and materials is an essential means of developing these worthy qualities. Students' initiative and resourcefulness are necessary for handling apparatus and materials for setting up an experiment, arranging for a demonstration or a project. Sometimes pupils have to improvise, adjust and repair parts of an experimental arrangement. This engenders resourcefulness and manipulative skill. Pupils' initiative is warranted when the pupils have to participate in planning and arranging for a demonstration or an experiment in the laboratory. Group work helps develop co-operation, friendship, mutual understanding and sociability among them.

F. Science rooms and laboratories

Science teaching is different from the teaching of other subjects for the fact that here the theoretical lessons are accompanied or followed by practical work with apparatus and materials. considerable part of the time spent in learning science has to be used for experimental work, either in the classroom as a demonstration or in the laboratory as individual or group laboratory work. Hence, there is a need for adequate classroom facilities and laboratory accommodation in teaching of science. Laboratory experience is the most useful and fruitful of all science activities. Since all the pupils do not acquire the same kind and same amount of experience as other types of learning activities like an individual laboratory work, laboratory experience therefore is much more valuable. A laboratory usually means a large room with necessary facilities for the students to do practical work. For Higher Secondary schools there should

be separate laboratory facilities for doing practical work in physics, chemistry and biology.

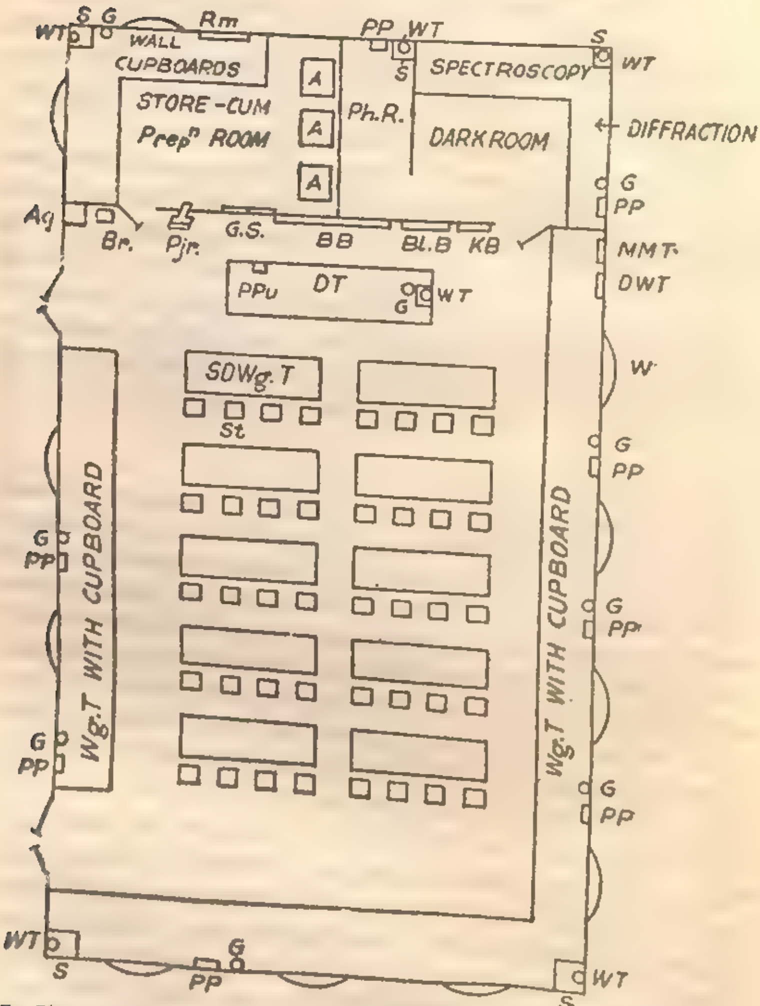
For teaching general science it is advisable, from economic point of view, to have a general science room equipped with facilities for doing all types of activities connected with learning science—theoretical lecture, demonstrations and laboratory work. The same room will serve as al-purpose room.

The science room should provide an environment congenial to learning science. Here the pupils should receive not only the knowledge of science but also acquire better understanding of science and its applications in our everyday life. The science rooms should be so designed as to give opportunity for pupils to perform self-designed experiments and to find answers to their problems. In short, the science room should provide all sorts of educative experiences relating to science.

G. General science room

A science room should contain a blackboard, a bulletin board, display tables, and other audio and visual aids. There should be provision for hanging charts and diagrams and for placing projection equipment. The room should be of optimum size which may vary according to its use to serve as a lecture room, a laboratory or a combined general science room. A combined general science room, in addition to the above mentioned aids should contain an aquarium, a terrarium, a science library and a science corner. The demonstration table should be placed in front of the pupils' desks at a suitable distance so that it is observable to all. It should be well-equipped with gas-taps, water-taps, sinks, power points to facilitate easy demonstration. There may be various ways of utilising the available space for practical work. An all-purpose science room, which is convenient for both theoretical and practical work in general science, is not quite suitable for teaching special branches of science. But, in view of the circumstances of our country, for teaching general science in High and Higher Secondary Schools, an all-purpose science room is the best arrangement. Provision should also be made, in this type of combined science room, for a small darkroom and a store and, if possible, the room should be fitted with exhaust fans. Power-points, gas-taps, water-taps aud sinks will be fixed depending upon the purpose

ALL-PURPOSE SCIENCE ROOM



S—Sink, G—Gas-tap, WT—Water-tap, Rm—Reflecting mirror A—Almirahs, PP—Power point, Aq—Aquarium, Br—Barometer, Gs—Ground glass screen, BB—Blackboard, Ph. R. Photography room, Pjr—Projector, Bl.B.—Bulletin Board, KB—Key board, SDWg. T—Students' desk-cum-working table, MMT—Max. & Min. thermometer, DWT—Dry & wet thermometer, PPu.—Power point underneath the table, W—Window, St—Stools.

and design of the science room.

In an all-purpose science room, the working tables can be used for doing laboratory experiments and as students' desks. An idea of such an all-purpose science room or all-purpose laboratory is given on page 150.

The size and design may vary according to circumstances. A room of (45 × 25) sq.ft. should be quite adequate for forty students. Here, stools or portable chairs or benches may be provided for them to sit when attending the theoretical class or demonstration; they will stand arround the writing-cum-working tables while doing experiments. The science room should get adequate natural light and the ventilation should be good. It is advisable to have a first-aid box at a convenient place in the science room or laboratory.

The water-taps and sinks should be fixed on the demonstration and the fixed side tables only. The writing-cum-working tables in the centre should not be fixed so as to make all types of classroom activities possible. On occasion, it may be necessary to have open area, and by shifting the movable working tables, the centre of the room may be made free. The fixed side tables should have storage cupboards where apparatus, equipment and chemicals can be kept. But the important apparatus and chemicals should be kept in the storage room. The doors and windows should be big enough and also be provided with blinds or arrangement for hanging black curtains to darken the room when necessary. Similarly, provision for extra illumination is as essential as the natural light.

In some cases, half of the lecture-cum-laboratory room may be used for theoretical class and the other half for the practical class. The floor of the science room usually receives rough and varied treatment; it should be hard, smooth and cemented. The whole floor area should be accessible for easy cleaning. Corners of the rooms, as far as possible, should be round in order to facilitate cleaning. There should be two doors each opening outwards to facilitate easy exit in case of an accident. Such a combined lecture-cum-laboratory room has obvious advantages over other types of accommodation, such as a gallery. It is economical in cost and space; it is compact and at the same time flexible. This arrangement provides an environment which helps realise unity in theory and practical work in learning

science. Talks on popular scientific topics with the necessary demonstrations can be arranged in the same room. The store-room, darkroom and all the necessary apparatus and equipment are readily accessible in such arrangements.

What has been discussed so far is about the "all-purpose" general science room. A consideration regarding various types of science rooms will reveal that these may be of three types: (*a*) all-science room or general science room, (*b*) semi-specialised science room for teaching different areas such as physical science, biological sciences, etc. and (*c*) special science rooms for teaching subjects such as physics, chemistry, botany, etc.

A few words may be said about the supplementary rooms in science, a provision for which affects science teaching.

(1) A dark-room in the science room can be used for doing experiments on light. Experiments or demonstrations on difraction, vacuum tubes or with spectometer are impossible without a dark-room. Many pupils may be interested in learning photography also. Only a dark-room can help in this case.

(2) Some gifted pupils may like to perform experiments in science which are beyond the abilities of the average pupils. They should be helped and encouraged to pursue such individual projects. To help them, the provision for single (small) room is imperative. Such rooms should be well-equipped with provisions to enable them to perform their experiments.

(3) In pursuing some biological problems, it often becomes inconvenient to continue in the general science room. For example, growing various types of plants or rearing animals cannot be conveniently done in the science room. In fact, this is impossible in many cases. Special rooms such as a green-house, a school zoo, if provided for this purpose, help better learning in these fields.

H. Science room for special subjects

Schools teaching elective subjects in addition to general science have to have separate laboratories for each special subject. In such cases provision should be made for the special needs of that particular subject such as apparatus and arrangements, techniques and procedures peculiar to that field of study. However, in spite of its special nature, there should be facilities

for demonstrations and experiments of general nature. This arrangement can be appreciated if we remember that enrichment of one field can be provided by calling upon the content of another field. Moreover, such an arrangement is unavoidable when the science room is used for teaching two or more fields in combination such as 'general science and biology' or 'physics and chemistry.'

For our Higher Secondary Schools teaching elective science in addition to the compulsory general science, we should have one general science laboratory and one laboratory for each special subject. But in general, the Higher Secondary Schools do not possess general science laboratories. A detailed discussion on planning and arrangement of special science laboratories in India is available in the report of the Committee on Plan Projects, Government of India (Report on Science Laboratories and Equipment in High Higher Secondary Schools committee on plan projects—1962). For determining the total area of the laboratories, the Committee considered the following factors:

(1) The number of pupils working at a time.

(2) The minimum space necessary for each pupil for comfortable work, taking into account the subject of study and the prescribed syllabus.

(3) The necessity for providing some flexibility in the accommodation to give an opportunity to the teachers to re-group the classes so that demonstration experiment could be carried out conveniently with the participation of the pupils.

(4) (*a*) Rooms for storage.

(*b*) Dark-room for certain experiments.

(*c*) Balance-room of chemistry laboratory.

(*d*) Room for gas-plant.

(5) Special provision necessary for certain laboratories such as fume cupboards for chemistry, museums for biology, kitchen and wash rooms for home science.

The Committee suggested the following specifications for different special laboratories:

Physics laboratory

(*a*) Power point—(220 V. 10 amps) on the side walls, one in the dark-room, one in the demonstration table and one for charging batteries.

(*b*) Plug points—(220 V, 5 amps) two points distributed in the laboratory and four points in the dark-room.

(*c*) Gas supply—one gas-tap on the demonstration table, three two-way gas-taps on the three tables on each side (underneath the tables).

(*d*) Water supply—one tap with a sink on the demonstration table, two taps with sinks for general use (one in the laboratory and one in the store-cum-preparation room).

(*e*) Work-tables—length 6 feet, breadth 3½ feet and height 3 feet (for four to work at a time). Physics work-tables need not have drawers or closed cupboards but may have intermediate shelves two feet wide and about one foot above the floor. The work-tables should have plain tops.

There should be stools of two sizes and almirahs or cupboards as necessary.

Chemistry laboratory

(*a*) Power points—(220 V, 10 amps) two for exhaust fans, four points evenly distributed in the laboratory, one point on the demonstration table and one point in the preparation room.

(*b*) Gas supply—two two-way gas-taps for each work table, one two-way tap on the demonstration table, one tap in the preparation room.

(*c*) Water supply—two taps to each work table with a common sink, one tap for demonstration table with sink, one tap for preparation room with sink.

(*d*) Work tables—(for a group of four pupils). Size 6 feet × 3½ feet and 2 feet 9 inches high with acid resistant top, with one sink in the middle having two taps and two reagent bottle racks on either side of the sink. The size of the rack should be 2 feet, 8 inches and 1 foot 6 inches high with intermediate tiers.

There should be a fume-cupboard and a wooden box for waste materials.

Biology laboratory

(*a*) Power point (220 V, 5 amps)—one point on the demonstration table.

(*b*) Plug point from light circuit (220 V, 5 amp)—one on demonstration table. Light points—one to each table for microscopic work.

(*c*) Water supply—two taps with sinks at work tables, one tap on the demonstration table with sink, one tap in the preparation room with a sink.

(*d*) Work tables—general work tables of size 6 feet × $3\frac{1}{2}$ feet and 2 feet 9 inches high with sinks one at each and (for dissection). Side tables of size $6\frac{1}{2}$ ft. × 1 ft. 8 inches and 2 ft. 9 inches high to be placed against the walls and near the windows for microscopic work; and having drawers and small cupboards underneath. There should be sufficient space between cupboards.

There should be small table rack and wall-shelves for keeping chemicals.

The total laboratory space requirement suggested by the Committee for twenty-four pupils is (same for each laboratory, i.e., physics, chemistry, and biology) 640 sq. ft. (32′ × 20′) out of which 240 sq. ft. (12′ × 20′) may be used for the purpose of storage, dark room, etc. This is the minimum space that could be suggested for twenty-four pupils working at a time.

I. The science teacher and laboratory work

Since learning science is actually doing science, individual laboratory work should provide an opportunity to the pupils to experiment their own ideas relating to the scientific scheduled item of laboratory work. There might be some pupils in the group who are supposed to complete items of experiment scheduled in the annual list of laboratory work. For the usual items they have the guidance or manual giving directions to perform the experiment. But if a pupil with special ability can think of a problem related and relevant to the given experiment as a corollary, he should not be discouraged. He should, in fact, be helped by the teacher to pursue his specific interest and skill. Even apparatus not needed in the usual experiment, if required, should be provided to the pupils. The teacher may have to take a little extra care and additional work in such cases. But the science teacher has the responsibility to encourage and nurture talent.

Science laboratory work involves danger too, if one is not careful and cautious. In the laboratory the pupils, who are novices unacquainted with such situations, will be prone to accidents if they are not cautioned. This involves the foresight of the science teacher. In the laboratory, the students have to

handle high voltage electricity, fire and also dangerous chemicals. A direct contact with high voltage lines is fatal. The teacher of science has to warn in advance, the pupils in the laboratory working with high voltage, give necessary instructions on preventive and precautionary measures and, in addition, keep constant watch when they work directly with high voltage lines or handle and use such apparatus and equipment working high voltage. When the pupils work with burners or inflammable and explosive substances in the laboratory, the teacher needs to be equally careful with the pupils. He should keep the fire extinguisher in working order and also sufficient quantity of water in the laboratory. Special care should be taken while working with oils, petrol or petroleum products, sodium, phosphorous, etc. In case of electricity, the main switch should be located in an easily accessible place.

Working with strong acids and alkalis like concentrated hydrochloric acid, sulphuric acid, nitric acid and concentrated potassium hydroxide, sodium hydroxide or even concentrated ammonia is always dangerous. For such accidents of burns, sufficient quantity of water, dilute sodium bicarbonate and highly diluted acetic acid should be kept handy. For phosphorus burns, water and dilute silver nitrate solution are necessary. Some common gases generated in the laboratory like hydrogen sulphide, chlorine or bromine when inhaled in excess, are poisonous. Smelling ammonia gas and washing the mouth with sodium bicarbonate gives relief in such cases. Cuts and bruises may be sustained while working in a laboratory. The first aid box should always be available for use with all the chemicals and ointments required to treat for cuts, wounds, corrosion, poisoning, fainting, bleeding, fire burns, etc.—bandages cotton wool, Dettol, adhesive tapes, elastoplasts, knife, scissors, pinchers, etc., common patent medicines as aspirin, milk of magnesia, Burnol, Borolin, Anacin, Iodex, eutheria, iodine, etc., as well as boric acid, glycerine, vinegar, castor oil, alum, etc.

The laboratory work should enable the pupils to discover the truth by themselves. The science teacher should move among the different groups of experimenters to encourage and stimulate them in their work and to clarify their misconceptions, if any; and also correct wrong procedures. The pupils should be allowed to progress at their own pace so that the more able and the less

able get equal opportunity to carry out experiments. The faster ones should not be interrupted in their work but should be advised to proceed with further experimentation if possible in the science clubs. The teacher can utilise the services of such pupils in improvising teaching aids during the science club activities. There are many varieties of teaching aids which the teacher can prepare in the science club with the help of the students. In the lower classes, the science teacher should take precaution about possible danger while collecting scientific materials and botanical and zoological specimens during excursions and field trips.

The science teacher should maintain the following records:

1. Stock register of chemicals. This register should contain the names of the chemicals and their description. The record should be made in alphabetic order. There should be monthly and, if necessary, weekly checking of the stock register. This will also serve as stock register for consumable articles.

2. Permanent stock register. This register should list all articles, apparatus, equipment, models and specimens (with description) which are non-breakable or non-consumable and thus permanent in nature. These are usually made of metal or wood or unbreakable hardware. These may also be listed alphabetically with other details such as date of purchase, number or quantity, name of the manufacturer, etc. Any article or equipment out of order should be noted as such in the remarks column.

3. Stock register for breakable articles. This lists all articles made of glass and China-ware such as beakers, troughs, thermometers, and models of other breakable materials.

4. Order register. This register should contain names of all articles, apparatus, equipment, chemicals, specimens, and models which are procured and received for use in the laboratory. The different columns in this register should indicate the date of order, order details, name of the firm, price, number or quantity purchased, date of delivery or receipt, date of payment, voucher details and also remarks about the quality of the materials. It would be useful to have a copy of the voucher attached in this register at its appropriate place. This register may have a section specially reserved for recording articles received gratis or as donation.

The science wing may also maintain a 'Requirement Register' to note down any new item that might be required for doing practical work in science. This register will come handy when time comes to place orders for purchase of equipment for the laboratory.

10

Aids for Teaching Science

. . . I give thanks to God, who has been pleased to make me the first observer of marvellous things unrevealed to bygone ages. . . . I have observed that they move around the sun.

—Galilio Galilie

A. Introduction

Aids of all sorts are meant only to help in teaching and not to act as a substitute for teaching nor to replace the teacher. Aids make teaching realistic and effective, and these aids are meant to supplement the teaching. The effectiveness of the use of aids depends upon the ingenuity and skill of the teacher who has to examine the necessity and suitability of the aids. He has to think out for himself the right hour and the right place for handling the teaching aids according to the demand of the circumstances.

The sensory aids in teaching effect economy of time in learning which becomes vivid when the teaching is accompanied by sensory aids. Since science learning has its basis in first-hand experience of the pupils, we should provide them resources and materials where they can see, hear, feel, smell and taste. If the teacher honestly tries, he can make the class-room a place of direct experience. Though this has a limited scope, much of the teacher's effort should be to bring to the science room real things from the environment and to arrange them so that the total situation becomes conducive to science learning.

The laboratory, no doubt, gives an opportunity for direct experiences; but on many other occasions, the pupils have to be taken out of the class room for direct experience. The school garden, the local museum and the zoo, field trips, excursions to

industrial sites, meteorological observatory, wild life sanctuary give direct experience to the learners.

It is a fact that all the experiences cannot be provided directly. To experience or observe an actual situation may, in many cases, be very expensive, dangerous or beyond the resources of the school. In such cases, it is necessary to provide representation of the real thing or situation. For example, it may not be possible for our schools to send pupils to see a geyser situated in another country or a cyclotron or an aircraft factory situated at a long distance away from the school. These can be brought to the classroom through motion pictures or filmstrip projections. Even the inside of an eye or a living cell has to be exhibited through models and illustrations. Thus, we see the importance of sensory aids in teaching science. A wise teacher will never ignore the use of sensory aids in science-teaching.

Besides audio and visual aids to the teaching of science, other sensory aids involving the senses of smell, taste, feeling are also useful in effective learning. For example, the smell of a flower or a chemical helps the pupils to recognise them well. The sweetness of different kinds of sugar or the sourness of different kinds of acids, taste of salts and bases help the pupils to ascertain the qualities of these things better. Real ice and dry ice (solid carbon-di-oxide) may not, in some circumstances, be distinguishable from a distance. If the pupils can feel them with their hands, they can definitely have a clear idea of the difference between them.

B. Use of audio-visual aids in teaching science

Audio-visual aids to instruction refer to the materials of teaching which are intended to effect learning through means other than mere reading a printed page or listening to spoken words. Some of the audio-visual aids are—objects, specimens, models, sketches, diagrams, maps and charts, graphs, cartoons, pictorial illustrations, photographs, slides, filmstrips, motion pictures, epidiascope projections, paintings, bulletin boards, museums, zoos, dramatisations, gramophone records, radios, radiograms, tape recorders, televisions, etc. But the mere use of audio-visual aids does not guarantee effective learning. The aids must be adapted to the intellectual maturity and the previous experiences of the pupils. These must be integrated into the classroom teaching.

The teacher should be familiar with the advantages and the limitations of aids. Otherwise, a poorly planned use of audio-visual aids may only reduce the effectiveness of teaching.

Aids are never meant to replace oral or written methods of teaching; neither can they substitute direct experiences. In fact, audio-visual aids are meant to supplement and enrich the usual method of teaching. Aids also vary in their effectiveness according to the degree of reality. Real objects and specimens should always be preferred to visual representations such as photographs or slides. For example, when a lesson on butterfly or toad is taught in the class, the teacher should collect an actual butterfly or a toad rather than a photograph or a slide projection on them. When the actual specimens are not available, the visual representations should invariably be used to make the lesson effective.

After conducting an experimental investigation, C.D. Jayne came to the conclusion that the teachers should not assume that "the visual experience is so effective that other types of experience should be eliminated in its favour."[1] In fact, for effective learning, there should be a proper integration of different types of experiences. The teachers should bear in mind that the audio visual aids should make the teaching more interesting, meaningful and effective. It should not be taken as a form of entertainment. But many teachers tend to think that the use of a large number of audio-visual aids will make the class more interesting. In fact, such a class becomes a ludicrous show and the whole lesson turns out to be a jumble of irrelevant displays.

Teachers using audio-visual aids for teaching science should observe the following principles:

(*a*) The materials should be carefully selected on the basis of need, purpose, accuracy and facility of use and should be attractive but economic from the point of view of cost.

(*b*) The use of aids should be an integral part of teaching and the materials should be integrated with the content discussed.

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1. C.D. Jayne, "A Study of the Learning and Retention of Materials Presented by Lectures and by Silent Films", *Journal of Educational Research*, 1944.

(*c*) The materials should be studied by the teacher who should teach and explain while exhibiting them.

(*d*) Materials used should not be too many. The aids used should enrich the present experiences of the pupils, enlarge their environment, promote intellectual curiosity and foster a favourable attitude.

On the whole a proper use of audio-visual aids should make the teachings of science, more fruitful and effective. It has been found that about eighty-five per cent of the knowledge is gained through the sense of sight. We often use the well-known phrases like "Things seen are mightier than the things heard" or "One picture is worth a thousand words". These only emphasise the importance of the visual aids in teaching. A good teacher will never underrate the value of these statements.

C. Advantages and limitations of audio-visual aids

Audio-visual aids have many advantages. Objects, events or scientific phenomena of the past or of far off places can be brought to the classroom through photographs, paintings, sketches or drawings. Sound films and recordings can make these more vivid. Audio-visual aids give information about inaccessible places or areas. Similarly, the aerial view of large areas on the surface of the earth are possible with the help of aerial photographs. Microscopic materials can be observed by magnifying them and even a very faint sound can be made distinctly audible by amplification. Flash photographs and time-lapse photographs are invaluable in making many types of study possible. The dangerous and most expensive experiments can be filmed and exhibited safely at least cost. Often, the actions of complex machines or other devices cannot be explained in working conditions. A series of models and illustrations, part by part, makes it possible. Radio, television, records and tape-records are considered important for disseminating knowledge and have wide applications in modern educational programmes.

These audio-visual aids have limitations too. The most obvious limitation is the lack of reality in them. A representation cannot be as vivid and as interesting as the real situation. The flat pictures, diagrams or slides of three dimentional objects cannot really give the impression of three dimensions. Moreover, if the pupil is not familiar with the objects or things, he may

not be able to realise the actual object or thing from the two dimentional representation of it. Sketches and diagrams often lack details. Photographs can distort the real thing. A photographic representation depends upon the angle at which photographed, the lenses used and the lighting provided. Models may also give a distorted representation. The materials used to make the model may give a wrong idea about the substance of which the real object is made. For example, the model of an eye made of plastic, cement or clay cannot give the concept of the soft fleshy membranes and the fluid inside. Moreover, the scales of proportion in all parts of the model, either in case of a diminutive model or an enlarged model, cannot be maintained accurately. Audio-equipment, too, can distort sounds, the fidelity of sound depending on factors like quality of the pick-ups, amplifires, speakers, frequency range, etc.

D. Various aids

1. Collected materials

Collections such as objects, specimens and models are very effective teaching aids. Moreover, children have natural love for collecting such materials. These being three dimentional articles, experience of the learners becomes more vivid. Out of these three, objects rank first as these are real.

Objects: Objects are real things. For example, a flower, a bird or an insect, a toad or a fish, a telescope or a microscope. The pupils should always be encouraged to collect such objects while teaching about them. Objects put the pupils in direct contact with the real things. Museum and zoo are important sources where the pupils can come across real things which the school cannot provide.

Specimens: Specimens rank next to objects. When the teacher talks about flowers in general and represents all flowers by a typical flower, (say, a China-rose) then it is a specimen. But if he teaches about the characteristics of the China-rose itself then it is an object. Similarly, if the teacher is describing rocks and represents all rocks by a piece of quartz or marble then these are specimens. But if he teaches about the properties of quartz or marble itself, then these are objects. A specimen is a sample

of a particular type of object or a part of the object.

Hence, a thing may be an object or a specimen depending upon how it is used. The teacher should, in co-operation with his pupils, collect all important specimens, especially the local ones, about which he is to teach in the class and preserve in the science room. This is not a difficult job; the pupils can easily collect local biological specimens. The school should procure other specimens which the pupils cannot collect. The science teacher should make a list of all the essential specimens, including the rare specimens, which the school should possess. These specimens should be placed in the science room in such a way that the pupils can have a look at them any time they please. If there is no school museum, provision should be made for proper display of all types of objects, specimens and models in the science room. It is essential that the science teacher knows how to prepare various types of preserving solutions.

Models: Models, though not as effective as objects or specimens, are very useful in teaching certain concepts and principles of science. In fact, models are intended to simplify, thereby making it easier to understand the form and function of the object or thing about which it is difficult to gain direct experience. They are, however, not real things; neither are they true in size or colour. Models are simply replica of a thing or object. They may be larger or smaller than the real thing; may represent the whole or a part of it. Or they may or may not represent the working condition. But, even so, with the use of models, many ideas can be made comprehensible to the pupils, which is not possible with flat pictures.

Many models can be prepared in the school and others procured. Science teachers should use models when it is impossible to obtain the object or a specimen of the thing about which he is giving lessons. Enlarged models of the eye, ear, teeth, animal skeletons, sections of plants and its cells, human skeleton, atoms and molecules, etc., or working models of a steam engine should invariably be used while teaching about them.

2. Designed materials

There may be a wide variety of designed materials. Two important desirable qualities of the designed materials are simplicity

and attractiveness. They should be simple but clear and distinct. Well-designed and properly coloured materials such as pictures, posters, charts and diagrams are very effective in teaching and at the same time attractive to the children. These should, however, be used during teaching in continuity and sequence.

Flat pictures: The use of flat pictures is quite popular in teaching sciences for the reason that these are either free or inexpensive. These can be obtained from old magazines and periodicals. Even in scientific catalogues, advertising pamphlets, or other illustrated industrial publications and weeklies, the science teacher can find material which can be used in teaching. Moreover, such material can be easily procured and does not require much care for storing. They can be projected on a screen by an opaque projector (epidiascope) to enable the whole class to study.

But it becomes best effective if the pupils can study the pictures individually under the guidance of the teacher. Ideally, a flat picture should be attractive, true to size and shape and should exhibit the details necessary for the purpose.

There are some disadvantages in the use of such pictures. Often they do not represent the true colour; distort the relative shape and size. Sometimes, they contain excessive details. The science teacher should collect suitable pictures from magazines and journals and photographs and keep them in a picture-file for future use.

Charts, diagrams and graphs: These terms are flexible in their meaning. A chart may be diagrammatic or graphic; it may also be a combination of these. For example, a chart may, through a series of diagrams, show the various parts of a flower or different types of leaves. The diagrams in a chart usually exhibit the contents in outlines with minimum pictorial representation. It may be used for conveying an idea or concept of a scientific principle, to compare and contrast the properties of an object or a thing, to represent a comparative data or to explain the working of the different parts of an object such as a complex machine. All charts are generally give short explanatory notes about the drawings. Often a single chart can be used to represent more than one idea. Colours may be used but precaution should be taken so that the chart does not become a confused colour display.

A chart is a flat surface upon which diagrams are drawn with names of the parts or short notes about them. The best example of a chart is the 'Geological Time-Chart' which shows the development of animal life through the geological eras. The main purpose of a chart is to make the idea which it represents simple, clear and easily comprehensible. A chart may be used for initiating a discussion or for reviewing. It can also be used for testing the pupils.

The teacher should encourage the pupils to make charts, diagrams, posters under his guidance. These should relate to the topic or topics discussed in the class. Charts may be drawn on subjects from any branch of science. It is, however, not feasible for the teachers and the pupils to make all the charts. Important and essential charts must be procured from scientific or commercial firms.

Diagrams are also effective aids for teaching science though in a sense, a little abstract in comparison to other aids. This is because, facts or ideas are expressed in a skeleton form in a diagram.

It is advantageous to use charts because they are easy to use. But they have limitations too. A bad chart can confuse the very idea it represents. Moreover, all ideas cannot be represented on charts. But, even so, the school should provide the pupils with materials necessary for making charts and diagrams within the range of their ability and under the guidance of the science teacher.

Graphs: Graph is a visual device to represent quantitative aspects of facts or ideas. It may be used singly or with other designed materials. The use of graphs not only focusses the attention of the pupils to the particular aspect the teacher wants to clarify, but it also familiarises the pupils with the statistical data and their uses. A graph may be designed to express the quantitative relationship between several constituent events or facts or their relationship to the whole. Like charts, graphs may also be used to initiate a discussion.

There are various types of graphs and their design depends upon the purpose. A bar graph is usually used for comparing two or more quantities, indicating the facts either by varying the width or by varying the length of the bars. In a vertical bar graph, the bars are placed vertically on a horizontal base-

line and in case of a horizontal bar graph, the bars are placed horizontally on a vertical base-line. In each case the lengths of the bars indicate the values which may be determined from the respective base-scale. In some cases, a single bar may be divided into parts to express relative comparison of facts. Such a graph is called component bar graph. The different parts may be coloured or shaded. A horizontal bar graph should always be preferred for the fact that it is easier to compare horizontal distances. When, in addition to the relative comparison, it is necessary to show the relationship of the parts to the whole, a circle graph is used. The constituent sectors of the circle represent the fractional values compared to the whole. For curve graphs and area graphs, a 'squared' graph paper is usually used. Curve graphs have wide use in science and industry. A picture graph represents the data through pictorial symbols. Such a graph is especially interesting to the pupils as the pictorial symbols have likeness to the object or thing represented. A graph should be attractive, neat and accurately drawn and should be easy to interpret.

Besides these, there are other designed materials which may be used in teaching science. These are cartoons, maps, globes, etc.

3. Visual implements

Projection equipment used in teaching are more than mere supplementing the work of the teacher. In the developed countries these aids have long been used as an integral part of classroom teaching. Projections make teaching highly stimulating because they are not only attractive but very often dramatic. They bring into the classroom things which are difficult for the pupils to experience otherwise.

However, benefit drawn from these equipment depends on their proper use. Moreover, the type of such aids to be used varies with the situation. There are limitations to the use of these equipment too, for example, films or slides usually meant for mass instruction do not provide for individual differences nor do they help pupils solve problems. But an expert teacher can use them to make the over-all instruction programme successful.

Opaque projector: An epidiascope can be used as an opaque

projector and as a slide projector. A magic lantern is usually used for projecting slides. In any modern projector there are accessory devices with which it can either be used as an opaque projector, a slide projector or as a film-strip projector. There are also varieties of handy and portable film-strip and slide projectors.

Various types of charts, diagrams, graphs, pictures or photographs in books and journals and even on a printed page can be projected on a white screen with the help of a projector. This makes them visible to the whole class. In the absence of a white screen, such materials may be projected on a white wall. The science teacher should select material relevant to the topic he is to teach. An opaque projector also enables the pupils to draw enlarged diagrams of those materials. The room should be well-darkened if possible, otherwise it should be made as dark as the circumstances permit.

Microprojector: A microprojector projects enlarged pictures of objects or a microscopic slide on a screen or a white wall. This enables the whole class to see instead of a single boy observing through the microscope. Very strong light is focussed on the microscopic slide and the rays pass through the objective and the eye-piece. In the process the image is magnified, and the magnified rays are then thrown on a screen with the help of an additional device. The teacher can explain the slide to the whole class. The device also enables the pupils to draw enlarged diagrams of the contents of the microscopic slide. The size and the quality of the projected image depends upon the intensity of light and the magnification of the microscope.

Motion picture: The use of educational films and film projectors in science-teaching is complex and expensive. Technically, a film projector is more complicated than other types of projectors. Usually there are two types of film projectors: (i) the 35 mm. film projectors and (ii) the 16 mm. film projectors. Out of these two types the 16 mm. projectors are always recommended for classroom use because they are smaller in size, lighter in weight and easier to operate. They are portable. The educational films help teaching in various ways. A film enables the whole class to observe and presents continuous and dynamic events before them. It creates a sort of a dramatic situation in the classroom. One of its important advantages is that it presents

real situations of moving objects and enables the pupils to observe movements which, otherwise, is not possible. Motion pictures can be used for introducing or overviewing a unit of science, for creating and solving problems and also for summerising and review. Films can also be used for showing applications and uses of science and for supplementing the classroom lessons.

It should be remembered that the films are tools or aids in teaching science. The effectiveness of any aid depends upon how it is used. This fact is applicable to the use of motion pictures also. But, however efficiently it may be used, it cannot serve as an independent device. In other words, it cannot take the place of a teacher.

In selecting a film, the teacher has to decide the type of film suitable for his class. A general scientific film may be shown to all the pupils of the school in order to create interest in science, but a lesson-film should be shown to the particular group for which the film has been planned. The teacher should review the film before projecting it in the classroom, prepare the pupils for the content of the film, make himself ready for interpreting the film and also plan appropriate follow-up activities.

Another type of educational film is an 8 mm. endless film-loop. It repeats itself. It is a short film used to represent repeative actions. Each film exposes a single concept. Film-loops are comparatively cheaper and can be shown with the help of a film projector with an extra-attachment devised for the purpose.

Filmstrips and slides: A filmstrip is a long 35 mm. film consisting of a series of frames. Each frame contains a drawing or a photographic print, or a combination of both. These films are projected with the help of a filmstrip projector or an epidiascope to run vertically or horizontally. A modern projector provides for both types of projections. A filmstrip-projector or a slide-projector is easy to operate, less expensive and portable varieties of such projectors are available.

The pictures on a filmstrip are arranged sequentially, numbered and usually supplemented by captions on the frames. Slides, too, may be arranged in order and numbered but will have to be interpreted verbally. The slides and the filmstrips can be used in different ways and for different purposes. A filmstrip can be used to show the different stages of a process

separately. It has one advantage over movie pictures; a single frame of a filmstrip can be kept projecting on the screen over which the teacher can talk and explain. Or a frame which has already been projected may be brought again by winding backwards and reprojected. The frame can be kept in position as long as the teacher desires. This is not possible in the case of movie films.

Filmstrips and slides can be stored safely for a long time and in a small space. In many aspects filmstrips and slides are more useful than motion pictures. They can be used for introducing a topic or to summarise; or during class lessons. It is the duty of the teacher to select proper filmstrips or slides appropriate to the grade of the pupils. Necessary explanations and questioning should accompany the filmstrip or slide projection.

Television: A television is a combined visual and audio equipment and represents the effect of both a radio and motion picture simultaneously. A television brings the world into the living room or a classroom. It has served as a powerful means of communication as well as education the world over. In the western countries, television has been used as the most effective aid for teaching in the classroom. Instructional televison programme has grown much popular and useful. It was found that the TV lessons were more advantageous than classroom teaching in the sense that it is more economic, interesting, attractive and can make use of such costly and intricate apparatus and rare materials as well as other audio-visual aids that cannot be availed of by the schools. The follow-up activities after a TV lesson inculcate the habit of discussion, criticism and clarification. A well-organised TV instructional programme can become the most effective and potent aid to the teaching of science.

4. Audio implements

Records and record players: The modern teaching methods not only make use of the visual equipment but the audio equipment as well. Gramophone records on scientific topics can be procured from commercial firms dealing in educational films and records. Young pupils can sit around a gramophone and listen to it. Records can also be used to reproduce natural sounds of animals and birds. Moreover, records can be useful in

studying the characteristics of various types of sound pitch and quality of sound produced by various types of vibrating bodies.

A record player, usually electrically driven, can also be used for the purpose. Long playing records are widely used for educational purposes. Such records can be played for a much longer time. The record player is designed to play at various speeds; usual turn-table speeds are $33\frac{1}{3}$ rpm. (revolutions per minute) 45 rpm. and 78 rpm. The long playing records are played at a turn-table speed of $33\frac{1}{3}$ rpm. and our usual records are played at a turn-table speed of 78 rpm.

Tape-recorders: Tape-recorders serve a very useful purpose in teaching. They have many advantages over other types of audio-implements. A tape-recorder is portable and can easily be taken to any place for recording. It reproduces the recorded sound with higher fidelity and can be edited. Battery operated tape-recorders can be used in rural areas where there is no electricity.

Radio broadcasts: Radio broadcasts can also be a valuable teaching aid. Popular talks on scientific topics should be broadcast from the radio stations especially for the young pupils. Such talks, in addition to giving scientific information, create interest in the minds of the listeners for studying science. The AIR in the special programmes broadcast for children brings scientists and experienced science teachers for talks on scientific topics or to discuss the biographies of eminent scientists. The use of radio is now widespread. This can be a useful agent for disseminating scientific knowledge over an extensive area. When the radio talk is broadcast during school hours, the school should organise the time-table to include radio listening. Such talks are, however, not meant to replace the teacher but to help him in teaching science more effectively. The radio instruction programme is prevalent in the developed countries.

In addition to the above audio-visual aids, the school should possess the following visual aids. Some of these may be made by the teacher himself with the help of the pupils.

Aquarium: An aquarium in the classroom creates an environment for the study of science. The young people usually like to observe the movement of animals, their colour and voice. Birds and fish are excellent substitutes to satisfy the curiosity of the

young people. An aquarium may represent complete natural environment. It is beautiful to look at and a valuable aid to study small aquatic plants and animals. The pupils get an opportunity to acquire first hand experience of many interesting events of aquatic animal life. They can observe and study the plant-animal relationship. The pupils can see how the aquatic animals and plants collect their food; how they grow; how they reproduce and how they interact to external stimuli. The aquarium is usually a rectangular glass box; and it can be easily made by the teacher. The classroom aquarium should be sufficiently big. The aquarium helps pupils acquire valuable concepts such as: water contains dissolved air (oxygen), many plants and animals live in water, plants and animals are interdependent, fish have special organ for moving freely in water, etc.

While setting an aquarium, it should be cleaned and a layer of sand, of about one inch thickness, should be spread at the bottom. Over it a layer of small stone pieces should be placed and then covered with some other materials such as shells. It is then filled with water. The aquatic plants such as velesneria, hydrila, moss should then be placed before snails or fish are put in it. It should be noted that neither too many plants nor too many fish should be put in the aquarium.

Terrarium: A terrarium represents a complete land environment just as an aquarium represents the complete water environment. Its size may vary according to purpose. Ordinary acquarium containers may also be used for terrariums, but a glass container, large enough to hold a few plants and small animals can serve the purpose. For young children a terrarium is as interesting as ana quarium and in addition, a terrarium permits greater variation in the types of environment to be illustrated.

It may be arranged to represent a bog-type terrarium showing how plants and animals live in wet places or may represent plants and animals of hot and dry lands; or it may contain certain plants and animals living at different elevations on the surface of the earth.

A terrarium may be prepared like an aquarium. At the bottom, a layer of sand and small stones should be placed. Around the edge of the base of the container, a band of moss

may be placed. A handful of charcoal may be scattered over the sand layer to act as absorbant. Then it is covered with a few inches of moist loamy wood soil prepared by mixing soil or sand with decayed leaves. Over it, different plants and small animals should be housed. A few rocks and fungus-bearing branches of trees add to its effectiveness. If desired, a small artificial water-pool may be prepared. Small toads, lizards, and other locally available insects and animals may be placed in it. In addition to mossess and ferns, locally available slow-growing plants should be raised. The terrarium needs occasional watering. Too many plants and animals should, however, be avoided.

A terrarium, if properly arranged, serves as a good instructional medium. It is interesting, attractive, and cheap; it contributes to learning various concepts regarding plant and animal life on the land surface.

Bulletin board: It may either be placed by the side of the black-board in the science room or any other convenient place where the pupils can easily see it. A bulletin board may be made by the science teacher in co-operation with the pupils.

Pictorial material such as photographs, coloured pictures, diagram, charts, textbook illustrations, newspaper cuttings, magazines and even books or booklets may be displayed. It may also exhibit any commendable work by a pupil or pupils.

The material displayed should be relevant to the topic or unit which is being taught in the class; these should be removed as soon as the topic is over. It will be worthwhile to give the responsibility of taking care and maintenance of the bulletin board to the pupils. This will help in creating a sense of responsibility in them. The bulletin board, in addition to serving as a source of supplementary information, serves as a motivating device too. It can also be used by the pupils as a medium of developing their creativeness and other special abilities such as drawing, writing, collecting, etc.

5. Science museum and biological garden

A school should also possess a science museum and a biological garden. These should be set up with the help of the pupils. A convenient site should be selected within the school compound for laying a biological garden to contain various types of local

plants and also rare plants. It should have a small pond in a corner where fish, toads, frogs and other aquatic animals should be reared. The presence of rats, rabbits, earthworms, lizards, birds, etc., makes the garden an interesting place for the pupils; they feel pleasure in coming to the school. Various types of flowers and vegetable plants should be grown and the pupils should be trained in taking care for growing them. Many essential concepts of plant and animal life can be taught with the help of a garden.

It is relatively easier to set up a school science museum if accommodation is provided by the school. The young pupils love collecting things and if the science teacher encourages them, there will be no dearth of science materials for the museum. Making a museum with the help of the pupils is an interesting and motivating task and offers a wide range of interests and satisfaction. Its value lies in the pupils' activities associated with collecting and arranging the materials. The pupils should be allowed freedom for selecting and collecting materials for the museum. In fact, they collect things that interest them. Rock specimens, models of eye, ear, etc., seeds, fruits, leaves, shells, feathers, butterflies or any type of interesting specimen may be collected. The science teacher should, with the help of the pupils, arrange the materials systematically and label the specimens clearly.

E. Field trips

These are purposeful visits to places of scientific interest and provide valuable experience in the process of science learning. A science teacher should arrange such field trips or visits to local centres such as factories, gardens, farms or museums. In every place, the community resources provide immense possibilities for educative experience in science. Field trips or visits should therefore be organised to enable the pupils to gain a first hand knowledge of science and its application. Field trips motivate the pupils to learn science and stimulate their interests. In addition to gaining knowledge, the pupils get an opportunity to collect materials for the school museum or zoo. The scientific information, facts and principles become more realistic to them and they see the relation between science and the society. In short, they learn to appreciate science. Through a field trip the

pupils learn to co-operate amongst themselves and also with the members of the community. They learn to think critically and apply elements of scientific method. A field trip enables the pupils to get a clear idea about the lesson or topic that is being taught. It provides an excellent opportunity for correlation.

Though a field trip usually means a biological excursion or a nature-study trip, the term can be applied to any activity outside the classroom in which the pupils participate. A field trip is essential for completing a project and to supplement the class-work; it is an excellent method for creating and fostering the spirit of scientific enquiry among the pupils. Such a field trip must, however, be pre-planned and the visit must be purposeful. The value of field experience is greatly increased by providing suitable follow-up work. The pupils should be guided to sum up and organise their learning in the field trip. They should make charts, diagrams and models related to the field trip and arrange to exhibit the collected materials. The bulletin board can be well utilised for the purpose of display of photographs taken during the field trip. They should write on the connected topics, hold discussion on their activities in the field trip (or visit) or on the problems arising out of their experiences during the trip. The teacher should help them solve their problems by suggesting relevant books, journals, and magazines for further reading.

A field trip may vary in duration and organisation from one of a few hours to a extensively organised lasting a day or more. For full benefit, a field trip must be carefully planned. The pupils should be involved in planning the trip keeping in view the purpose, conduct of the trip, and the necessary follow-up activities. The field trip should not be taken as a holiday trip; though it is a sort of an enjoyable activity, it should be considered a serious undertaking. The young pupils, however, need guidance. The teacher may prepare a guide sheet, details of which will vary according to the type of the trip. The pupils may also participate in preparing the guide sheet. It should contain the physical details of the trip such as the route, transport, dress, provision for meals, first-aid box, etc., and the details relating to the learning activities such as apparatus and materials to be taken with them, collection of data, records, reports, books and paper or the pupils' responsibility and

conduct. The *pupils* should be grouped and each group made responsible for one type of work. In short, all the pupils should be actively involved in the organisation of the trip.

Without proper follow-up activities, the field trip loses much of its value. The follow-up activity should begin from the first meet after the trip. It may include a general discussion on the trip, writing a report, displaying collected materials and souvenirs, preparation of models, preparation of suggested further reading in the library, arranging film shows relating to the trip or a talk by a qualified person on the area visited.

An unplanned and badly organised field trip without proper follow-up work is nothing but waste of time and energy. The science teacher should survey the available materials or phenomena of scientific interest or any other opportunity for educative experience in the community before arranging a field trip. Some of the places which may be visited are: radio station, telephone exchange, airport, weather bureau, museum, botanical garden, zoo, bird or animal sanctuary, mines and quarries or oil producing centres, electricity generating station, paper mill, cloth mill, rice mill, sugar mill, saw mill, hospital, railway station, dairies, farms, tea-gardens, water works system, chemical or other industrial plants, oil refinery, rubber factory, soap factory, glass or ceramic factory, dams, dykes or irrigation system, gas plant, research laboratories, shipyards and docks (in case of sea-side areas), green fields and forests, stores and markets, ponds, lakes, streams, antiquarian department, fish farms, etc.

The pupils should be aware of the purpose of the trip. For elementary grade pupils, the purpose may be:

(*a*) to collect various types of seeds;
(*b*) to collect various types of leaves;
(*c*) to study birds;
(*d*) to study flowers;
(*e*) to collect rocks;
(*f*) to study animal behaviour; or
(*g*) to study the life-cycle of toad or frog, etc.

The teacher should decide the type and standard of the purpose in accordance with the level of the pupils and the demand

of the circumstances. Some activities that are suitable for higher classes are mentioned below.

F. Student discussions

This is another procedure for effecting better understanding and broadening the experience of the pupils in the field of science. Though discussion means talking over a subject, actually a purposeful discussion is much more useful and effective educative experience than mere talking. Through discussions the pupils learn from each other. A discussion may be taken as a bond between other methods and procedures or as a medium of transition from one method to another. In a discussion pupils get an opportunity to exchange opinions.

A discussion provides for individual thinking and the pupils gain an insight into the problem of discussion. It is not only an intellectual process, but a social process too. All the pupils in a group can freely join in the discussion. But if the discussion is not well directed, it may digress too far. For this reason, the pupilis should be made aware of the purpose of the discussion. The teacher plays an important part in the discussion; he should guide and give direction to the pupils to discuss, stimulate them to add vitality to the discussion, help them to keep the discussion lively, interpret on some occasions, organise and summarise the essential points of the discussion, and lead the pupils to draw conclusions. A discussion may be organised before or after a field trip, a class lesson or a film show or an arranged talk on some scientific topic. But while beginning a discussion before an actual activity, such as a class lesson or a field trip, the teacher should be careful lest it becomes uninteresting and unfruitful. Since the pupils usually do not possess sufficient background to initiate the discussion, the arrangement for an initial discussion should be made only when the teacher is satisfied that the conditions are suitable. Follow-up discussions are always lively.

The teacher, while conducting a pupils' discussion, has to be tactful in dealing with the situation. He should neither allow a group to predominate over the other nor discourage the others. He should act as a moderator rather than a leader, and at the same time keep the discussion moving. He should acknowledge all suggestions and should tactfully reject the unacceptable

suggestion without thwarting or offending their sentiments. He should encourage all the pupils to participate. He should also see that the physical conditions are suitable; all pupils should be able to hear and see each other. During the discussion, the teacher may have to face many questions from the pupils; in such a situation he should enable them to find the answers themselves, instead of telling them the answers directly.

G. Committee work

Pupils' committee, like group discussion, can also add valuable contribution to the process of learning science. The pupils of a class may be put into a number of small groups or committees and the office-bearers elected. The advantage of having a small group is that pupils with similar interests and abilities are brought together. Pupils of similar aptitude can work and gain maximum benefit. There are various needs of the pupils which may be met effectively through a small group activity. Here also, as in class discussions, pupils get an opportunity for exchange of ideas.

After forming a number of small group committees, special tasks may be assigned to them. One committee may be asked to assist the teacher in setting up demonstration, another to take care of the science library or the science museum, still another to serve as an advance party to collect information regarding the place selected for a field trip by actually visiting the area, and so on. Some committees may take up small investigations in the laboratory, while other committees may take up the work of repairing apparatus or preparing visual aids for a demontr· tion or a class lesson. There may be many types of tasks the field of school science which the pupil committees can take up. The tasks alloted, however, require careful planning.

H. Students' reports

Pupils, during participation in a field trip or a project, may have different experiences. Each pupil has his own feelings and appreciations. Reports on various aspects of an educative experience by pupils, individually or in a group, should always be encouraged. In preparing a report and reading it out to the class, the pupils are actively involved in the learning process. A pupil or a group may be asked to prepare a report on a particular

topic by consulting books and encyclopaedeas in the library. Obviously, they have to delve deep into that particular field of study. Or a small group or a commitee may be asked to observe a particular aspect of a project or a field trip in greater detail and prepare a report on that aspect for the whole class. Similarly, a group or a committee may be entrusted with the responsibility of interviewing an expert, say the head of a power-supply center in connection with information regarding the power supply system. This report may be a part of a broader unit of study such as "Electricity and its application to the community".

I. Science clubs

(*a*) *Value of a science club*: Science club gives great impetus to science learning. It provides an opportunity to the pupils to express their creative abilities in the field of science and fosters development of new ideas. This movement has been widespread throughout the world. The environment and facilities a science club provides are most congenial for the expression of pupil's talents. Individuals differ in their interests, abilities and skill. It may not be possible to cater for individual needs in a routine science programme. But a science club is the place where the pupils can engage in their individual interests. In the developed countries, science clubs form an integral part of the school science programme. The important difference between the science club activities and the classroom activities is that the classwork is formal and the pupils are asked to do something, whereas a club is informal and the pupils are free to choose their activities. In a science club the pupils work not to satisfy their teacher but themselves. A science club provides freedom, whereas in a class the pupils have to conform to a strict system.

Young pupils are always eager to do something and a science club is the place where they can work and develop their skill. Pupils who desire to study deep into a particular area of science, may do so in a science club. Moreover, there is some carry-over from the science club to the classroom. Pupils who work in the science club are more enthusiastic and take more interest in the classroom activities. The regular class becomes more lively due to the effect of their supplementary work in the science club. Some pupils may like to do a special experiment which they may

not be able to do in the school. A science club offers opportunity for such advanced scientific activities.

One important educational value of science club activity is its social aspect; the pupils learn to work in co-operation with others. They learn to understand each other and to share responsibilities. They work together and this doing of manual work in the science club, as in the laboratory, helps create an attitude congenial to avoiding consciousness of their socio-economic status. Poor and rich, all work together.

Science club is a place where we can look for science talent and our future scientists. Science talent search has now become an important programme. The science teacher, who is always in contact with the science club members, can help in this regard. He is usually the sponsor of the school science club and its effectiveness of working depends on his interest and enthusiasm. He has to devote time and energy for the progress and development of the science club. As the key-man he keeps the science club working.

(*b*) *Organisation of a science club:* The following points should be considered before organising the club:

1. Accomodation and facilities needed for a science club—such as rooms, apparatus, etc.
2. Type of the science club: whether it is to be a general science club covering a wide range or areas of scientific interest or restricted to a specific area of study such as a biology club, nature club, etc.
3. Size of the club—such as number of members in the club.
4. Selection of members and the office-bearers.
5. Dates and place for club meetings, etc.

Usually, the head of the institution should be the chief patron and science teacher, the sponsor of the club. Membership should be open to all science students and also to other students interested in science. The recurring expenditure should be met from the collection of pupils' subscriptions. Initially, however, the school or any other body should bear the expenditure for establishing the science club. The science club should form two bodies:

(*i*) The General Body consisting of all the science students—the Headmaster as the patron and the science teacher as the sponsor. The members may also be of two types—ordinary

members who pay subscriptions at the rate fixed by the club. Active members are those who take keen interest in the club activities and actually work with apparatus and equipment. They may have to pay little extra fee.

(*ii*) The Executive Committee should consist of the patron, sponsor, president, vice-president, secretary, assistant sectretary treasurer, librarian and publicity officer. The office-bearers will have responsibilities as defined.

In the science club organisation the sponsor plays the key role. He is the man who organises and arranges the activities for the club members. He should see that the science club activities are worthy, useful and effective creative work and not a show.

(*c*) *Aims of science club*: A science club should

(*i*) encourage individual and group activities in the field of science;

(*ii*) create interest and enthusiasm to persue science as a hobby;

(*iii*) inculcate scientific attitude, critical thinking and develop creative abilities;

(*iv*) enable them to realise science and its application to our life;

(*v*) provide opportunity to develop individual skill in science; and

(*vi*) develop the habit of reading extra science books, of taking part in debates and essay writing on scientific topics.

(*d*) *Activities for science clubs*: Various types of activities may be suggested for science clubs. But primary consideration is pupils' interest. The type of activities may vary according to the circumstances and the locality. A few activities are suggested below:

(*i*) Hold discussions, meetings, debates on scientific topics.

(*ii*) Arrange excursions, field trips or visits to the places of scientific interest such as museums, zoo, botanical garden, factories, etc.

(*iii*) Prepare charts, diagrams, models and hold science exhibitions and science fairs.

(*iv*) Improvise apparatus or collect specimens for the science museum, such as plants, insects, rocks or other materials.

(*v*) Celebrate birthdays of eminent scientists.
(*vi*) Arrange popular scientific talks by local, invited experts in the field of science.
(*vii*) Read reports or papers on individual work.
(*viii*) To render school services or community services in the aspects of health and sanitation.
(*ix*) First aid demonstration by an invited doctor.
(*x*) Preparation of soap, ink, bleaching powder, paper, face powder or tooth powder, paints and other materials of everyday use.
(*xi*) Making slides of botanical specimens.
(*xii*) Making a school biological garden.
(*xiii*) Making and maintaining aquariums.
(*xiv*) Photography, electroplating, etc.
(*xv*) Preparation of scrap books and albums.
(*xvi*) Drammatisation on science theme.

Talks may be arranged on various topics of local interests such as:

Mystery of nature; nature of power and energy; atomic energy; birds of the locality; plants of the locality; animals of the locality; pre-historic animals; science and safety; great men of science; the microscope; the telescope; the telephone system; radio and TV broadcasting; photography, etc.

J. Science fairs

A science fair is another useful activity for effecting better science instruction. It serves as a forum for display of useful activities carried on in the science club. Science fairs provide incentives to the pupils to work on something in the field of science fit to be displayed to all. Moreover, the pupils learn much about science from the work displayed and in association with other pupils. A science fair also provides an occasion when the parents and the people of the community become acquainted with the school's activities. This creates a consciousness among the people towards science learning. It also serves as a centre for disseminating knowledge of science. Moreover, while working and organising the school science fairs, the pupils involved get much help and guidance from teachers, judges (for the exhibited science apparatus etc.), senior students and visitors who might be experts in the field of science. Here, too, the

valuable outcome is the sense of social co-operation in working together.

The National Council of Educational Research and Training, Delhi, develops and organises science fairs all over the country at district, regional and the state level. According to the NCERT, the objectives of the science fairs are:

1. To give impetus and encouragement to the students to try out their ideas and apply their classroom learnings into creative channels.

2. To provide opportunities to students to witness the achievements of their colleagues and thereby to stimulate them to plan their own projects.

3. To popularise science activities of the students among all, so that, further improvement in standards of performance may be achieved.

4. To give encouragement and recognition to the bright and energetic students, who have special science talent.

5. To identify and nurture the future scientists of India.

6. To provide the much needed forum for the activities of the science clubs and individuals.

7. To bring the people of the area in touch with the school and to meet teachers and students.

A science fair may include activities such as:

(*i*) Essay competition and debate on scientific topics.

(*ii*) Symposium on scientific topics.

(*iii*) Reading papers and reports by the pupils and then discussing on the topic of the paper read.

(*iv*) Exhibition of models, charts or other graphic materials, specimen collections, science magazines, journals and books or improvised apparatus and special aids prepared by the pupils.

(*v*) Film shows on scientific or educational topics.

(*vi*) Individual and group experiments.

K. Science exhibition

It has been mentioned elsewhere that school science exhibition can be one of the valuable activities to help science learning. The school should organise science exhibitions periodically and the students should be encouraged to display the exhibits prepared by them individually or in groups. The science club provides them facilities for making their exhibits. In addition to

the pupils' contributions, local commercial firms may be approached to lend some of their exhibits for display in the school science exhibition. Such exhibitions provide incentives to the pupils to prepare scientific exhibits and to collect material for display. Science exhibits prepared by the science class or the members of the science club serve as instructive material to other pupils of the school or the people of the community who come to witness the exhibition. In fact, science exhibitions create an environment congenial to science learning.

The exhibits displayed and demonstrated in the science exhibition should be self-explanatory. Each exhibit should be labelled properly and the captions written in bold and distinct letters. Pupils, who demonstrate experiments in the exhibition, should rehearse and practise beforehand. Proper follow-up activity, such as discussion, essay writing, reporting, etc., increases the value of the science exhibition.

L. Photography

Young pupils like to take photographs and are always eager to handle a camera. Photographic process can help teach some aspects of science. If there are facilities in the science section of the school, for developing films and printing photographs, i.e., camera, dark room and photographic materials, the pupils may form a photography club. While using a camera and learning to develop and print, the pupils learn many facts and principles of physics and chemistry. They gain an idea about the intensity of illumination. lens, focal length, principle of image formation and the chemical reactions between the developer and fixer and the photographic materials. Photography is an important and useful hobby for the school students.

M. Dramatisation

A stage performance is always interesting to the young boys and girls. Dramatisation on scientific theme can be an effective device to motivate the young pupils to learn science. A drama on a scientific theme combines arts and science. This is a very valuable aspect of dramatisation. It helps to create an impression of unity in arts and science in the minds of the pupils. Such a drama may be based on a science fiction, on a scientific

concept or on the life of a scientist. Radio dramas on science themes may also be written out and broadcast for the school pupils. The language and the theme of drama and its appeal should be appropriate for the pupils. The subject of the drama should be interesting, within their comprehension and should be important to everyday life. It should fit into the school curriculum.

11

Correlation in Science Teaching

Why does this magnificent applied science which saves work and makes life easier bring us so little happiness? The simple answer runs: Because we have not learnt to make sensible use of it.

—Albert Einstein

A. Importance of correlation

Students' experience in science learning can be greatly enriched by correlating it with other fields of study. Seience cannot be taught in isolation. During teaching some fact, phenomenon or principle of science, immediate reference should be made to its application and to other factors to which it is related. The application of science to our life and in agriculture, engineering, medicine, communication, etc., is widespread. Obviously, science should not be taught without reference to its relations with these fields. In addition to relating science with life, it should be correlated with various other school subjects and the different branches of general science itself. No artificial division of general science into various branches should be made. General science should be taught as an integrated whole and not as a collection of various unrelated topics from different branches of science. Such unrelated teaching should give place to the 'unit,' 'project' or 'topic' method of teaching science. A 'project' provides unique scope for correlation. Cooperation, between the science teacher and the teachers of the different subjects, is of great value in the process of teaching science as an integrated whole.

B. Correlation with life

Modern man lives in a scientific society. We see, everywhere around us, the application of science. Moreover, many natural phenomena that we see in our everyday life can be explained with the help of simple scientific principles. There are scientific principles in every simple event of our life. Examples of scientific facts and principles are available in any type of local environment. In the modern world, there is no place which has not been touched by achievements of modern science. Even in rural areas, there is electricity, radio and the application of scientific methods in cultivation. The teachers should, while teaching science, always refer to its application to life. In every topic, there can be innumerable local examples, whether it is an urban area or rural. Such correlation makes the teaching of science interesting and realistic. The pupils feel that science really matters to everybody and they begin to take interest in the world around them.

While teaching a topic on water supply or power supply in the town, the pupils may be taken to the local water-supply centre or the power-house. The application of scientific principles relating to water pressure and electricity production, and their use for the benefit of man, can be explained on the spot. All other implications or correlated events, in connection with these topics, may also be discussed. If possible, a visit to the nearest hydro-electric project may be arranged. This will enable them to realise how nature has been harnessed in the comfort and service of the human race. In a rural area, probably a co-operative 'fish-farm' can be visited, when the topic taken up for study in the class is fish (major topic—animal life) or the pupils may be taken to the nearest pond to study the behaviour of toads, when the topic for study is toad (major topic—animal life) In referring to the application of science, examples should have a rural background in rural areas and an urban background in urban areas. Photography (use of camera) and cinema are very interesting for the young pupils. The teacher should refer to these while teaching principles of image formation. Spectacles are also easily available examples to make immediate reference to the application of scientific principles. Water purification, disinfectants, insecticides, manures, etc. provide examples of everyday use of science.

C. General science and other school subjects

Science can be correlated with almost all the school subjects. In some cases. the co-operation between teachers of various subjects makes correlation more convenient. For example, the 'gas laws' cannot be taught unless 'ratio and proportion' is done in the mathematics class. Similarly, many principles of science cannot be discussed, unless trigonometry is done in the mathematics class. Moreover, the same topic is often discussed by different subject teachers from different points of view. A mountain provides to the physics teacher an example to discuss centre of mass or difference of atmopheric pressure at the top and at the bottom, or the gravitational pull towards it. The geography teacher discusses the topography or the type and composition of the mountain or the type of vegetation on it. A history teacher will probably describe its strategic position in the defence of a country or its historical background. The teacher of literature would perhaps like to describe the physical beauty of the mountain. The impact of these different types of treatment becomes much more valuable, when the teachers of different subjects co-operate and take up a topic at the same time.

(i) *Science and arts*: There are many common fields of study, which the science teacher as well as the arts teacher can deal. Music and colour are good examples. Motion and rhythm, mechanics and the design of instruments are other examples. Science students are required to make intricate drawings, and charts, diagrams, graphs etc, in physical sciences. They often have to make models and draw diagrams of apparatus and equipment used in the laboratory. In zoology, they often have to draw living and non-living animals and the enlarged diagrams of what they see through the microscope. Here they need the imagination of an artist. Therefore, science (or the scientist) is dependent on arts (or the artist). There are also examples where art is dependent on science. Work in arts depends on production of good colours and paints, chemistry of dyes, production of good brushes, pencils, etc. There are some persons who are able to contribute both to science as well as to arts. An example of such a personality is Leonardo da Vinci.

(ii) *Science and mathematics*: Science without mathematics is inconceivable. No science can be exact without the application of mathematics, directly or indirectly. Mathematics may be said

to be the language of science. Physics and astronomy are based on mathematics. Other branches of science and technology such as chemistry, biology, medicine, geology, geography, agriculture, engineering, transport and communication all use mathematics. In the modern time no branch of science is intelligible without adequate mathematical background. For studying science, the knowledge of graphs, equations, trigonometry, co-ordinate geometry and plane geometry, statistics, calculus and other arithmetical processes such as ratio and proportion, variation, and technical drawing are necessary. Co-operation between the science and the mathematics teacher is essential. As has already been mentioned, many scientific topics cannot be taken up unless the mathematical tools needed are taught in the mathematics class. For example, kinetic theory of gases needs the knowledge of co-ordinate geometry; the use of sextant is impossible without knowledge of trigonometry; the relation between the distance and time for body under the action of gravity or properties of lenses, require knowledge of quadratic equations. Even simple measurements of area and space require the knowledge of mathematics. In teaching mathematical principles, plenty of examples are drawn from the field of science. Subjects like mathematical physics, mathematical chemistry, applied mathematics, dynamics, etc., show great interdependence of science and mathematics.

(*iii*) *Science and history*: Everybody has heard the story of Archimedes and the king of Syracuse. Archimedes found a solution to a problem, when the king asked him to examine the purity of his crown. Archimedes got the royal patronage in his search for scientific truth. Similarly, Aristotle, Newton and many other scientists received royal patronage. On the other hand, Galileo had to face quite the opposite situation. Many scientists had to work against the prevalent social trends to discover scientific principles. The events of history, when connected with the contemporary scientific discoveries, make the learning of science more interesting. The First World War may be connected with the leadership of Germany in the field of scientific achievements. The discovery of many scientific facts and principles are linked with reigns of certain kings. Writings on the progress of science and its impact on human society make interesting historical reading. The history of science is the history of civilisation

itself. The history of science is a subject equally interesting for both the scientists and history lovers. The books like *The History of Man*, *The Story of the Earth*, *The Story of the Atom*, *The Story of the Moon*, bear testimony to this. The wall-chart for historical events may be turned into a chart of scientific events by simply writing in the column, the outstanding scientific achievements or discoveries against each period. The science teacher and the history teacher planning their programme for teaching in co-operation with each other can make learning useful and interesting.

(*iv*) *Science and geography*: Many facts and principles of science and geography are common topics. Examples may be cited of topics on air, water, barometer, thermometer, rain-gauge, eclipse of the Sun and the Moon, motion of the planets, meteorological topics, etc. Geography makes use of the science equipment for its own purpose and interpretes the results. 'Chemistry of rocks' may be a topic for discussion either in geography or in chemistry. Similarly, the topic 'relationship between animals and plants' is a common topic for both science and geography class. A geography lesson often includes some facts or principles of science. The two subjects are inter-dependent. Tne lesson on climatic conditions of a place which refers to temperature, humidity and rainfall is difficult to understand unless the topic 'hygrometry' is done in the physics class. Realising this closeness of geography and science, the Secondary Education Commission has included geography in the science group.

(*v*) *Science and crafts*: In schools where craft has been introduced as a subject, pupils of crafts may produce material, valuable for science learning. The pupils offering wood work and metal work can improvise apparatus for science and also repair science apparatus and equipment. Crafts-work itself requires the knowledge of science. Science is essentially a practical subject and its relation with crafts is obvious. The knowledge of the structure of wood and chemistry of metals will facilitate better craft work.

(*vi*) *Science and language*. The pupils of science often have to write essays on scientific topics and notes on their laboratory experiments. They should be encouraged to write in distinct, lucid language. Science and language teachers have equal

respon sibilities in developing clear and accurate expression. After a field trip or visit to a place of scientific interest, pupils should be asked to write essays or reports on their experience. Science fiction is the result of knowledge of science and felicity of expression.

D. Correlation within general science

We have seen that there exists a correlation of science with various other subjects of study. It is still more true in the cases of different branches of general science which consist of elements of all the branches of science. These branches of science are inter-related. While teaching science, it is impossible to distinguish clearly between the various branches of science. If any artificial division of science is made into its various branches, it is just for convenience and not out of necessity. Any topic in general science may serve as a common topic of two or more branches of science. For example, the gas laws, electrolysis, air, water, cells, atoms and molecules, crystals, etc., are topics which may belong to both the fields of physics and chemistry. Manure, insecticides may be topics of chemistry, hygiene or physiology. The topic 'light' may be discussed in physics, physiology and hygiene. The lessons on the eye or the ear may belong to the field of physics or physiology. The barometer or the rain gauge may be topics of physics or geography. Oil' is a topic common to the field chemistry as well as geology. Various branches of general science may be correlated through topics of general science. For example, 'healthy living', 'cleaning', 'nutrition and food preparation', 'home management', 'use of first aids', etc., involve applications of various branches of general science. 'The working of our bones and muscles' can be compared with the working of various types of levers. Thus, physiology and physics (mechanics) can be correlated. 'Rest and sleep', 'digestive system', 'circulation of blood', etc., are common topics of physiology, hygiene and biology. Physical conditions affect the mental condition; thus, physiology may be correlated. 'Use of electricity in home' combines electricity (physics) and hygiene. 'Humidity' is topic which may be taught either in heat (physics) or in geography. Similarly, mariners compass is a topic which may come up for discussion either in physics or in geography. Every branch of science is developing

fast and each branch is becoming more and more dependent on other branches. Research in common topics is being done by specialists in various branches of science. The various special branches of science are being combined to form new areas of science such as bio-chemistry, bio-physics, geophysics, physical-chemistry, physical-geography, economic-botany, electro-chemistry, mathematical-physics, etc.

(*vii*) *Science and music:* To understand the working of musical instruments one requires knowledge of science. Sound recording and reproduction, equipment like the tape recorder, gramophone, sound film, amplifiers are all products of science. Resonance, vibration of string, drum and air-column and reverberation, idea of scales in music can be understood only with the help of science. For such a study, there is a branch of physics known as accoustics. A tabla or a mridanga is treated as a loaded membrane in accoustics, a sitar or guitar as plucked string, a violin as bowed string, a piano as struck string, a cymbal as a vibrating metal disc, etc. Music can now be made more appealing through the application of science. Electronics has brought about great innovations in the world of music.

12

Evaluation and Examination

If science is poorly taught and badly learnt it is little more than burdening the mind with dead information, and it could degenerate even into a new superstition.

—Education Commission (1964-66)

A. The current examination system

The pattern of education in India suggests as if the purpose of education is only examination. By examination is meant the usual essay-type written test introduced in India during the British period. In this type of test the learner can express his ideas, opinions, interpretation and analysis. It gives freedom for exposition of his knowledge, organisation of his thoughts and ideas, expression of attitude with regard to the information gained as well as his skill of expression. There is no possibility for guess work and in case of science, this type of examination enables the examiner to test the examinee in his mastery of facts, principles, concepts or theories of science or its application. It can also reveal his mastery of grammar, spelling and over-all organisation in the presentation of his knowledge. The student can also be assessed for his neatness of presentation and ability to summarise contents. Such an examination tests one's ability of written expression and the power of memorisation.

This type of examination cannot measure the objectivity, validity and reliability. It is subjective and the evaluation of the answers varies with different examiners. It gives importance to rote-memory of the learner. It lacks validity in the sense that it is unable to measure exactly what is meant

to be measured. In science examination, the propose of a question is to test the student's knowledge, skill and understanding of science and not his handwriting, spellings, grammar or his linguistic ability. These are not to be assessed in science examination. But the essay-type answers being subjective, the examiner is prone to be swayed by the exuberance or otherwise of these extraneous factors. Such tests are not reliable as the assessment or scoring of the same response varies not only with different examiners but also with the same examiner evaluating it at different times. An essay type answer therefore securing very high marks from one teacher may secure much lower marks from another teacher and the same teacher may award widely varying scores on the same answer at different times. It is therefore held that the success in an essay-type examination depends upon who examines the answer script and that, too, depends on when the papers are examined. Often, in the essay-type examination the language of a question may be beyond the ability of the pupils to comprehend. The questions in such examinations are hardly graded nor they can take care of the less able or highly able pupils. Some questions carry ambiguous meaning and do not indicate clearly the answer expected. A commonly held view is that the questions do not cover the whole syllabus and a pupil can chose to study only selected portions of the course to be able to sit for such an examination because the examinee is required to answer only some out of the total number of questions. Further, the essay-type examination is neither concerned with the objectives of education nor is there any feedback received from it for improving any aspect of the teaching learning process.

B. History of examination reform in India

Whatever be the merits or demerits of the present examination system, the undeniable fact stands that it only encourages cramming. The pattern of this type of examination is such that the students pay minimum attention to their studies during the year and at the end they cram desperately for the examination. The Indian Education Commission (1966) referring to this effect of essay-type examination said: "The evil of the examination system in India is well known to everybody. The baneful effects of the system on education in general, and secondary education

in particular, have been discussed in the reports of several committees and commissions etc."

This is true not only in the case of school stage but also for higher education also. The Indian Education Commission referring to the higher education said that the crippling effect of external examinations on quality of work in higher education was so great that examination reform had become crucial to all progress and had to go hand in hand with improvements in teaching. Even the University Grants Commission had to admit that, "if we are to suggest any single reform in university education, it should be that of examinations". In this connection Dr. B. S. Bloom, an internationally reputed expert on examination reform, referring to India said that the system of education in India "consisting of examinations, curricula, syllabi, textbooks, and methods of teaching has formed a ground conspiracy wherein everybody concerned with education has come to believe that learning is to be equated with rote memorisation". His remark continues to be valid even now, and all concerned are alive about the ill-effects of the present examination system and the need for reform in it.

We cannot avoid examination or similar assessment procedure as a measuring tool to test the progress or achievement of the learner, the effectiveness of the teaching-learning process and the whole school system or the education at large. Such a measurement process is also required to assess the relative ability, position or rank order of the pupils; to help the teacher to understand their pupils better as well as to correct their teaching methods. As already mentioned, the defects of the examination system had been pointed out at different levels by different bodies. The Secondary Education Commission (1953) was instrumental in starting the movement for examination reform in India. While reviewing the defects of examination at the secondary stage, the Commission recommended a new approach to evaluation and proposed measures for improving external examination and internal assessment. The new reform movement emphasised the modern concept of evaluation which has, by now, spread throughout the country. This was a revolutionary step. The new concept of evaluation was put forward by different agencies and organisations. But the essay-type examination cannot be rejected straightaway. The Secondary

Education Commission suggesting the reform said that the essay-type examination should be progressively replaced by the objective-type tests; comprehensive school records should be maintained by the schools containing information about all aspects of pupils' development to be considered in the final assessment and that the numerical scoring should be replaced by symbolic grading. The Commission also suggested allowing completion of public examination in parts.

C. The objective-type tests

The objective type tests have been advocated for various advantages such as follows:

(*a*) They are economic and less time-consuming.

(*b*) They are comprehensive and can be spread to cover the entire course.

(*c*) The subjective element predominant in the essay-type examination is practically absent. The tests are therefore objective and can be scored mechanically with a scoring key.

(*d*) They are valid and reliable if correctly framed.

(*e*) These tests are easy to administer and cover large population of examinees.

(*f*) The results can be made public quickly. But these tests do not examine such abilities as clarity of expression, organisation of contents, neatness in presentation. Nor is it possible to present one's opinion as in the essay-type examination. Further, in objective-type tests there is an element of chance and room for guess work too.

In any system of education, there must be some form of measuring tool to assess the effectiveness of education as a whole and the growth of the learners and success or efficiency of the teaching process, in particular. Examinations and tests are useful both as a check to the teaching as well as encouragement to learning. It is evident that both essay-type and objective-type examinations have their advantages and disadvantages, merits and limitations. As such, both the types of examinations have their place in the over-all measurement of the students' educational achievement. The All India Seminar on Teaching of Science (1956) also recommended the use of a combination of the essay-type questions, short-answer-type questions and objective tests in the external examinations. This

suggestion was made to minimise the subjective element in external examinations and to raise the validity and reliability of the examination system. The Indian Education Commission had recommended, as early as 1966, the use of the concept of evaluation rather than the traditional process of examination as the measuring tool.

The construction of objective type tests requires experience and insight on the part of the teacher. The process consists of the following steps: (1) Defining the objectives; (2) planning the tests in terms of learning outcomes; (3) construction of the tests; (4) administration of the tests; (5) scoring the responses; and (6) evaluation and interpretation of the results.

First of all the objectives of teaching science under each of the aspects of knowledge, skill and understanding should be selected, organised and classified. Then the behaviour patterns expected against the selected objectives should be determined. The stage or age group for which the test is meant, the duration of time, range of contents to be covered, the number of questions to be given and their difficulty level should be finalised. The questions need to be graded according to difficulty. The number of questions in different areas of knowledge, skill, application should be determined before-hand. The types of questions in the battery of objective tests may be (1) multiple choice type; (2) completion type; (3) alternate response type; and (4) matching type. Experience shows that the multiple choice type is more popular and common. While administering the tests, it is advisable that objective tests precede essay type tests. Proper attention should be paid to the correct sitting arrangement and physical conditions in the examination hall. Instructions, guidelines and scoring keys should be prepared in advance. After scoring the answer sheets, the final results should be evaluated and interpreted in accordance with the weightage given item-wise. A sample series of objective type tests and short answer type tests is given in Appendix.

D. Evaluation

Evaluation connotes a much wider concept than the conventional examination. It is more comprehensive, valid, reliable and objective compared to the traditional measurement system. The usual examination procedure only tests the achievement

aspect of the learners in some particular subject for a specified period, but the function of the evaluation procedure is to make a continuous assessment of all the learners' educational achievements attained through the educative processes in the institution. Evaluation includes examination but while the traditional examinations measure only the achievement skills and power of memorisation of the learner, the evaluation process is meant to report on the total growth in the personality of the learner as a result of the teaching-learning process. Evaluation is related to the aim of education and is the process for continuous examination in the development of the learners towards attainment of the aim. Evaluation proposes to make appraisal of the behavioural changes or the over-all personality development as a result of education. Thus, it guides the teachers in correcting and improving teaching so as to achieve the changes envisaged by the set objectives of education. Thus, evaluation is a comprehensive and continuous process meant to measure not only the achievements, skills and abilities of the learners but also to assess their habits, attitudes, aptitudes, understanding, appreciation and other faculties and behavioural changes to be attained through the process of education. According to the Indian Education Commission

> evaluation is a continuous process, forms an integral part of the total system of education, and is intimately related to educational objectives. It exercises a great influence on the pupils' study habits and the teachers' methods of instruction and thus helps not only to measure educational achievement but also to improve it. The techniques of evaluation are means of collecting evidence about the student's development in desirable directions. These techniques should, therefore, be valid, reliable, objective and practicable. As the common method (and often the only method) of evaluation used at present in India is the written examination, a natural corollary of the acceptance of the new approach will be to improve the written examination in such a way that it becomes valid and reliable measure of educational achievement. There are, however, several important aspects of student's growth that cannot be measured by written examination and other methods such as observation techniques, oral tests and practical examinations, have to be devised for collecting evidence for the purpose. These methods need to be improved and made reliable instruments

for assessing the student's performance and educational development.

The movement for examination reform gathered momentum with the establishment of the Central Examination Unit in 1958 and subsequently the State Evaluation Units in the States. Efforts had been made and are being made by the various State Boards of Secondary Education to improve the evaluation system but have not yet fully removed the major defects inherent in the traditional examination system. The new process of evaluation is yet to be adopted adequately in the external examinations. But, though some work has been done for the secondary level, no effort has been made for similar improvement at the primary as well as university stage of education.

The Indian Education Commission recommended that at primary stage (class one to four) the evaluation should help pupils improve their achievement in the basic skills and to develop the right habits and attitudes with reference to the objectives of primary education. At the middle school stage (classes five to seven), in addition to the written examination, due weightage should be given to oral tests as part of internal assessment. Simple teacher-made diagnostic tests should be applied and cumulative record cards in a phased manner indicating pupils' growth and development should be used. Further, the Commission recommended district level common external examination at the end of ten years' education using valid and reliable standardised tests, for inter-school comparison of the level of performance. The certificate at the end of the school stage should be accompanied by the cumulative record card along with the result of the external examination. External examination should be improved by raising "technical competence of paper setters, orienting question papers to objectives other than acquisition of knowledge, improving nature of questions, adopting scientific scoring procedure and mechanising of scripts and the processing of results." In respect of State School Boards certificate, there should be no remark about pass or fail but it should mention the candidate's performance in different subjects in which he appeared in the external examination. The school should also issue a certificate along with the Boards' certificate, indicating the student's achievements in the internal assessment

as recorded in the cumulative record card. The Commission also stated that the

> internal assessment by schools should be comprehensive and evaluate all aspects of student growth including those not measured by external examination. It should be descriptive as well as quantified. Written examination conducted by schools should be improved and teachers trained appropriately. The internal assessment should be shown separately from the external examination.

The Commission thus recommended holding of the first external examination at the end of class ten. The second external examination is to be held at the end of class twelve. This system is now in vogue in many States of India including Assam. There is, however, the equivalent course called "Predegree stage" run by the colleges under the universities in many States of the country equivalent to Higher Secondary stage in schools.

E. A good measuring instrument

A good evaluation tool should be:

(*a*) *Objective* : The scoring or assessment should not be affected by the bias or subjectivity of the examiner. The judgement of the achievements should not be affected by his personal likes or dislikes.

(*b*) *Valid* : The test should measure only what it purports to measure. If it is meant to measure the knowledge of scientific facts, it should measure only the knowledge of facts. Similarly, if the test is meant to examine the understanding of scientific concepts, it should do only that and should not be attended for other abilities such as his manner of presentation, sentence patterns or grammatical construction.

(*c*) *Reliable* : The tests should enable award of same credit when examined by different examiners or at different times by the same examiner. The scoring should be the same under any varying situation.

(*d*) *Clear and unambiguous* : The test should not contain any question which may carry ambiguous meaning or is not comprehensible to the students. The language should be simple and clear enough so that meaning is easily understood.

(*e*) *Comprehensive* : The test should be comprehensive enough

to cover all the items in the entire course. The tests should cover items on knowledge, skill, application, aptitude, appreciation, etc.

(*f*) *Appropriate* : The questions in the test should be appropriate to the age, ability and aptitude of the students. They should be properly graded.

(*g*) *Interesting and thought provoking* : The test items should be so prepared as to be thought provoking to the students. It should evoke interest in the examinees and encourage reasoning and reflective thinking.

(*h*) *Easy to administer and score* : The test prepared should be convenient to administer to a large number of examinees and should be easy to score the answers quantitatively. The instructions and guidelines incorporated in the test-set should also be simple, clear and comprehensible to the examinees.

It may be mentioned in this connection that the preparation of such evaluation tools is no easy task. It requires experience and training to frame evaluation tools that satisfy all these requirements.

Evaluation aims to test the outcomes of educational objectives in terms of behavioural changes in the learner and thus endeavours to evaluate the total personality of the learner. The process can also indicate defects in the system of education as a whole and the teaching-learning process in particular. A good evaluation system helps improve the curriculum and can test the appropriateness of course designs. The process of evaluation can help diagnosis of the weaknesses in teaching-learning process and thus help in devising corrective measures.

Evaluation is a continuous and dynamic process. It envisages to test not only the achievements or abilities and skill of the learner but also his interest, understanding, appreciation, aptitude, attitude, sociability and other attributes of his personality. That is why the Secondary Education Commission as well as the Indian Education Commission laid special emphasis for maintaining comprehensive school records or the cumulative record cards, keeping continuous note of all aspects of the child's development. Other methods include observation techniques, oral tests and periodical examinations. The process of evaluation in science starts from selecting the right objectives of teaching science, defining the learning outcomes and developing the

related learning experience and then preparing appropriate measuring equipment and lastly evaluating the learning outcomes on the basis of the results obtained through the evaluation tools. For a total assessment of the learner's all round development, various types of evaluation tools are needed.

The objective tests, essay-type questions as well as the short-answer-type questions fall into the category of achievement tests. In addition, there are other methods and techniques of evaluation such as intelligence tests, aptitude tests, interest inventory, teachers' observation, oral examination, test of sociability, personality test, etc., which need to be used for evaluation of all aspects of the learner. To supplement these, the cumulative record card should be used. Work-experience, which has been included as a compulsory subject, can also be used to assess pupil's attitude towards work, creativity and manipulative skill, interest and aptitude toward science, sociability and cooperation during group-work. Practical work in the laboratory by pupils, if properly observed for assessment, will indicate their sincerity, cooperation, ability to take precautions, intellectual honesty, neatness, inquisitiveness, power of observation and judgement, deligence, accuracy, scientific organisation, problem-solving skill, skill of organising and analysing data, etc. These are valuable attributes of a learner's personality.

13

Lesson-Planning

Science corrects the old creeds, sweeps away, with every new perception, our infantile catechisms, and necessitates a faith commensurate with the grander orbits and universal laws which it discloses.

—Emerson

A. What is a lesson-plan

Planning of classroom lessons is essential for successful teaching. A lesson-plan gives direction to the teacher and checks haphazard teaching. It is a classroom guide for the teacher as a visualisation of the classroom experiences he desires to occur. The Dictionary of Education (Good) defines a lesson-plan as a teaching outline of the important points of a lesson arranged in the order in which they are to be presented; it may include objectives, points to be made, questions to be asked, references to materials, assignments, etc. Lesson-planning calls for intelligence, skill, ability and experience of the teacher. A lesson-plan reveals the approach of teaching and also mastery of the teacher over his subject. It, however, does not mean that the teacher has to follow it slavishly; he should use the lesson-plan as basis for developing the lesson through flexible instructional techniques. There is danger in depending solely on the lesson-plan. Some unforseeable event may occur in the classroom which may upset the previous planning of the teacher. In such cases, the teacher has to be resourceful enough to manage the situation; an unskilful teacher is sure to be in trouble in such a situation. A lesson-plan should, therefore, be conceived as a guide to effective teaching. It is advised that the lesson-plans should be brief and include the broad points only so that the teacher can treat the

details with freedom and according to the circumstances demand. The teacher should come well prepared so that any departure from the pre-planned arrangement does not cause any difficulty.

B. Pre-requisites of lesson-planning

Effective lesson-planning depends upon various factors. The knowledge of the physiological development and the intellectual maturity of the pupils is essential before making a lesson-plan for the class. Similarly, a knowledge of the needs, interests and abilities of the group helps him to make the lesson-plan suitable for the group. Moreover, the knowledge of the psychology of learning, principles of teaching, previous knowledge of the pupils of the class, effective mastery of the subject matter, etc., are essential pre-requisites of lesson-planning. The teacher who prepares the lesson-plan should realise the importance of the various steps of a lesson-plan. It demands sufficient experience of the teacher to plan classroom activities to develop understanding, interest, aptitude and skill of the pupils in addition to the scientific knowledge in all its aspects—scientific terms, facts and principles, ideas and concepts, etc. In a lesson-plan, there should be scope for creative activities by the pupils and should provide opportunity for critical thinking. Questioning is an art; it requires experience on the part of the teacher to frame proper and adequate questions which will lead the pupils to think. A lesson-plan, however carefully prepared, will not serve as an effective teaching tool unless the teacher knows how to conduct the class, even departing a little from the set plan (but still based on it), in order sustain the interest of the pupils throughout the period. The science teacher should be able to plan for the duration of the time available because a science lesson invariably includes practical demonstration or practical work by the pupils which requires much time.

C. Values of lesson-planning

Lesson-planning is a device essential to economise time and to make the teaching systematic. It enables the teacher to aim at objectives appropriate to the lesson and suitable for the class and thus guides him in the attainment of those objectives. A lesson-plan enables the teacher to cover a wider field in a limited time. Since the questions or assignments are previously planned, they are

thought-provoking and relevant. The important questions relating to the scientific topic and the application of science to our everyday life find relevance as planned rather than extraneous questions. The teacher feels confident with the lesson-plan by his side, because he is aware of the difficulties that may arise in the classroom and is prepared to deal with them.

A lesson-plan reminds the teacher of the specific goals to be attained through classroom teaching and gives him a clear picture of what is to be pursued and what is to be avoided. Planning a science lesson for the class requires selection and organisation of the subject matter of the lesson for presentation in the class. He also has to select the teaching aids and materials such as apparatus, equipment, charts, models, diagrams or films, etc., before giving the lesson. Moreover, it requires him to plan activities for demonstration or individual and group practical work. It also provides for planning activities to develop the other virtues peculiar to the teaching of science. Black-board summaries of the essential points, class tasks and home assignments are other important features of a lesson-plan. A lesson-plan enables the teacher to connect the present lesson with the previous lesson and the lesson that will come next and thus to maintain a continuity in teaching. Teachers should indicate in the lesson-plan the reference materials such as books and journals to be read in connection with the lesson and also arrange for field trips or visits if necessary which may increase the effectiveness of learning. Adjusting the lesson to the alloted time is a problem to be solved by the individual teachers.

D. Preparing a lesson-plan

A lesson should be planned immediately after the preceding lesson, because the events of the previous lesson are fresh in the mind of the teacher. The extent of content covered and approach followed is distinct in his mind. He also remembers the mistakes he committed so that in planning the next lesson, he can use his experience. He can also foresee the type of activity that will create interest and enthusiasm in his pupils. A lesson-plan usually includes the following:

1. *Statement of objectives*: The objectives of teaching the particular topic of science should, first of all, be stated in clear, unambiguous words. The whole structure and approach of the

lesson-plan will depend upon the objectives desired to be attained. Aims are too general and are directly related to the general aims of education. These should be remembered by the teacher rather than stating them. Objective may be divided into two categories—general objectives and specific objectives. General objectives are of general nature and cannot immediately be developed by the experiences of the particular lesson. They may be considered as reference objectives for the lesson. Specific objectives are those which can be developed and measured in the classroom. These may include the knowledge, skill, habits or attitudes which can be directly attained in the classroom. For example, in a lesson on thermometers, one of the general objectives may be "to develop in the pupils scientific attitude and spirit of enquiry" of the world around them; and one of the specific aims may be "to enable them to construct and graduate a thermometer." Similarly, in a lesson on dynamo, one of the general objectives may be "to develop in the pupils an understanding how energy can be transformed" whereas one of the specific objectives may be "to help them to know how a dynamo works." The specific objectives lead to the attainment of the general objectives.

2. *Apparatus and aids, etc.*: The apparatus and other teaching aids needed in connection with the lesson should be mentioned. A study of the content and the method will enable the teacher to decide the materials needed. He will, however, have to consider the available resources and facilities. The selection of apparatus for a demonstration or laboratory work and related reading materials or references, charts, diagrams, models, films or filmtrips, chemicals will depend upon their availability.

3. *Preparation* (*introduction or motivation*) : Before giving the lesson the teacher needs to know the pupils' previous knowledge. This is to know the background of the class and thus to prepare ground for developing the present lesson. Through proper questioning, the teacher should test the previous knowledge of the pupils and then introduce the lesson linking it with their previous knowledge. There may be various ways of introducing the lesson. It may be introduced through an interesting demonstration or telling of an interesting story of the discovery of the particular fact or principles or the biography of the scientist connected with it. Appropriate questions may be asked through

which the pupils may be led to realise the necessity of learning the new topic the teacher is about to present. Arriving at this stage, the teacher should announce the day's lesson. After introducing the lesson comes the stage to present the lesson.

4. *Presentation*: This is the stage of actual giving of the lesson, the time for the teacher to show his ability in selecting, organising and presenting the content matter, engage himself in appropriate activities, such as demonstrating, talking, questioning, supervising, giving black-board summary, or simultaneously evaluating and also providing activities to the pupils such as observing, taking notes of the salient features, helping in demonstrations, doing individual or group practical work. The pupils should be kept busy with one or the other type of activity. During teaching, the teacher should encourage the pupils to observe carefully, compare and contrast with similar events and lead them to generalise the principle taught in the class. Comparison of the present features with similar other facts and principles is essential in any type of scientific learning. The arrival at a generalisation by the pupils may not always be completely correct, yet it helps to attain the broader objectives of teaching the particular topic of science.

5. *Application*: In this stage, the application of the new learning to life situations is discussed. The pupils should be able to see the application of principles or the phenomena in their everyday life and also be familiar with their applications. They should be able to apply their knowledge of facts and principles to new situations. They may be asked to solve problems which involve the application of the facts or principles taught in the class. Tests may be applied or questions may be asked to test their knowledge or some creative exercises may be given where the pupils will have to apply their knowledge. This stage may also be used for the purpose of revision or recapitulation. At the end of the lesson-plan, the list of the black-board summaries should be given. This includes the salient points and principles to be used during the lesson.

Home assignments should be indicated at the end of the lesson-plan. Specimen lesson-plans follow:

SPECIMEN LESSON-PLAN 1

School—
Class—VIII
Average Age—14
No. of pupils—
Date—

Subject—General Science
Lesson Unit—Archimedes' Principle
Time—40 minutes
Teacher—

General objectives

1. To develop scientific interest, attitude and scientific thinking in the pupils.
2. To arouse curiousity and interest in scientific phenomena in the world around them.
3. To enable them to appreciate science and its application for the benefit of man.
4. To develop the power of observation of the pupils.

Specific objectives

1. To help the pupils to understand and verify the Principle of Archimedes.
2. To help them to realise the applications of Archimedes' Principle in our everyday life.
3. To make them familiar with the scientific terms and symbols involved.

Aids

1. Sensitive spring balances.
2. Hydrostatic balance with weight box.
3. Bucket and cylinder.
4. Big graduated cylinder, stands, beakers, threads, etc.
5. Pieces of sufficiently heavy stones.
6. Pieces of metals, wood, etc.
7. Charts, diagrams, pictures in connection with the lesson.
8. Usual classroom aids.

Previous knowledge

The pupils are already familiar with the experiences of drawing water from ponds, wells or rivers, with the help of buckets or pitchers.

Steps	Matter	Method
Preparation		After ascertaining their previous knowledge through suitable questions, the teacher will ask the following types of questions to motivate them for the present lesson—
	1. The bucketful of water weighs less when under water—it is easier to lift the bucket (any body) under water.	1. "As you have just expressed, most of you have the experience of drawing water from a pond or a well; when you lift the bucket, do you find any difference in weight as you lift the bucket above the water level?"
	2. Same experience with any other body.	2. "Do you think you will have the same experience with any other body immersed in water?"
		In order to introduce the topic, the teacher will perform a simple demonstration in co-operation with the pupils.
		He asks a pupil to fill three-fourths of the big graduated cylinder with water. He asks another pupil to tie a piece of stone with a thread and to tie the other end of the thread with the hook of the sensitive spring balance. He asks him to tell the class the weight of the stone as indicated by the pointer of the balance. He

Steps	Matter	Method
		then asks the pupil to immerse the piece of stone in the graduated cylinder (under water) keeping it hanging from the spring balance. Hs asks the following types of questions:
	3. The pointer of the spring balance indicates that the stone piece weighs less.	3. What do you observe?" (He asks some pupils to come to the demonstration table to observe closely). Pointing to the pupil holding the spring balance.
	4. Less heavy	4. "Do you now feel it more heavy or less heavy?
	5. Water level rises—the immersed body displaces water equal to its own volume.	5. "What about the water level?" All the pupils observe these phenomena carefully.
	6. Loss of weight of the body is equal to the weight of the displaced volume of water.	6. "Do you think there is any relation between the displaced water and the loss in weight?" Most of the pupils will not be able to answer this question. "Have you heard the name of Archimedes?" He then tells in brief the story of the discovery of the principle.

He then announces the day's lesson to prove that, "A body when immersed in water appears to loose a part of its weight equal to the weight of the displaced liquid."

Presentation		The teacher then performs the actual demonstration of

Steps	Matter	Method
		the principle with a hydrostatic balance and the bucket and cylinder in co-operation with the pupils. He arranges the class in such a way that the demonstration is observable by all the pupils. While giving the demonstration he asks relevant questions at appropriate time. They are asked to take note of the salient features. He asks questions such as—
	1. When the cylinder was immersed under water the position of the arms was displaced. When the bucket was filled with water, the arms returned to the initial horizontal position.	1. "Why was the position of the arms displaced? When did it return to the horizontal position?"
	2. It means that the loss in weight of the body is equal to the weight of the displaced volume of water.	2. "What conclusion can you draw from the experiment?"
	3. The principle holds good for any liquid.	3. "Will the same procedure give the same result if the liquid is changed?" The experiment is then repeated by replacing water with kerosene or any other liquid available.

Generalisation: The teacher then writes the generalisation on the black-board. "When a body is immersed in a liquid, it appears to loose a part of its weight equal to the weight of the displaced liquid."

Steps	Matter	Method
Application		The teacher asks them to write the principle in their note-books. He then asks some questions regarding the application of the principle in the service of man, such as—
	1. Floating bodies, boats, ships, rafts, etc.	1. "Can you give some examples where this principle has been applied?"
	2. A lactometer is used to test the sp. gr. of milk.	2. "How many of you have seen a lactometer? What is its use?"
	3. Submarines use this principle.	3. "Have you heard about submarines?"
	4. The weight of the ship is less than the weight of the displaced water.	4. "Can you explain why an iron needle sinks but a huge ship floats?"
		At the end, the teacher gives a summary of the lesson on the blackboard.

Home assignment

1. State the Archimedes' Principle and describe an experiment to verify it.
2. Explain why a piece of dry wood floats with major part above the surface of water.
3. Explain why an egg sinks in pure water but floats in salt-water.
4. Why does iron sink in water but floats in mercury?

SPECIMEN LESSON-PLAN 2

School— Subject—General Science
Class—IX Lesson Unit—Germination

Average Age—15 Time—40 minutes
No. of Pupils— Teacher—
Date—

General objectives

1. To arouse curiosity and interest in learning science.
2. To develop the power of observation.
3. To develop scientific attitude and scientific thinking.
4. To familiarise the pupils with the phenomena that occur in their natural environment.

Specific objectives

To enable the pupils to understand the process of germination and the conditions necessary for it.

Aids

1. Dry seeds of gram, bean or pea.
2. Germinating gram seeds.
3. Three-bean experiment apparatus (pre-arranged).
4. Other usual classroom aids.

Previous knowledge

The pupils are already familiar with the different parts of a dicotyledonous and monocotyledonous seeds. Some of them are also familiar with the process of germinating a variety of vegetable and flower seeds at home (without any understanding of the scientific basis for it).

STEPS	MATTER	METHOD
Preparation		After being satisfied that the pupils possess the necessary previous knowledge, the teacher, in order to prepare their minds for the present lesson, will ask questions of the following type.
	1. Embryo	1. "What is the important part of the seed?"

Steps	Matter	Method
	2. That is the structure from which the seed germinates.	2. "Why?"
	3. The axis.	3. "Which part of the embryo actually takes part in the process of germination."

Announcement

At this stage the teacher will announce that they will learn about the process of germination and the conditions necessary for it.

Presentation		The teacher now displays the apparatus and equipment on the demonstration table which are necessary for demonstration. He asks the following type of questions.
	1. The radicle	1. "You said that you have seen germination of common vegetable and flower seeds; did you observe which part of the axis comes out first?"
	2. The plumule	2. "Which part of the axis gives rise to the over-ground part of the plant?"
	3. The process by which the dormant embryo wakes up, grows out of the seed-coat and establishes itself as a seedling is called germination.	3. "Now, what do you understand by germination?"
	4. Soak in water and make provision for temperature.	4. 'Have you heard about the pre-treatment of seeds before sowing?"

STEPS	MATTER	METHOD
	5. Moisture, temperature and oxygen.	5. "Now, can you tell me what are the conditions necessary for germination?"
	Moisture—for softening the seedcoat and activities of the cell, protoplasm. Temperature — for the activity of the cell protoplasm. Oxygen—for respiration of the germinating embryo.	Here the teacher will demonstrate the three-bean experiment, which he has prepared. He will also explain the conditions necessary for germination of seeds. He will ask relevant questions during demonstration and try to achieve pupils' co-operation whenever there is scope for it.

Generalisation—The teacher elicits the generalisation from the pupils and writes it on the black-board. For germination, all seeds need moisture, temperature and oxygen.

Application		The teacher will ask questions of the type given below, to test their understanding.
	1. Epigeal and hypogeal processes.	1. "Have you ever observed any difference in the process of germination?"
	2. To provide temperature.	2. "Why are seeds often covered with plantain leaves or thatch in the seed-bed?"
	3. No	3. "Will germination take place if any of these conditions are denied?"

Home assignment

1. Try to germinate some pea seeds in your home garden.
2. Describe the three-bean experiment and draw your conclusions.

3. Describe the conditions necessary for germination and the importance of each condition on the process.

SPECIMEN LESSON-PLAN 3

(Prepared in terms of teachers and pupils activity)

School—	Subject—General Science
Class—IX	Lesson Unit—Flower, its parts and their functions.
Average Age—15	Time—40 minutes
No. of pupils—	Teacher—

General objectives

1. To develop scientific attitude in the pupils and to create interest for the objects of nature.
2. To arouse curiosity and to develop scientific thinking.

Specific objectives

(*a*) Knowledge
- (*i*) To make the pupils familiar with the different parts of a common flower and their relationship and functions.
- (*ii*) To enable them to understand the importance of flower.

(*b*) Skill
- (*i*) To study the structural and functional details of the flower.
- (*ii*) To study the method of dissection and to draw the parts.

(*c*) Interest
- (*i*) To learn the names of the flowers.
- (*ii*) To take interest in growing flowering plants in the garden.

(*d*) Attitude
- To develop the power of observation, appreciation and the systematic arrangement.

(*e*) Application
- (*i*) To collect decorative flower species.
- (*ii*) To study the method and technique of cult ation.
- (*iii*) To take interest in decoration.

Aids:

1. Common bisexual flowers.
2. Unisexual flowers.
3. Hair pins.
4. Magnifying glass.
5. Dissecting microscope.
6. Charts and diagrams, etc.
7. Usual classroom aids.

STEPS	MATTER	METHOD	
		TEACHER'S ACTIVITIES	PUPILS' ACTIVITIES
Preparation		The teacher will arrange the class and will try to motivate the pupils for the lesson by asking them questions relating to their previous knowledge — the probable questions may be asked on the seasons and their influence on vegetation, or on the different parts of a plant and their functional importance.	The pupils will try to answer the questions.

Announcement

Being satisfied with the answers of the pupils, the teacher will announce the day's lesson and will write it on the black-board.

Presentation	Brief structural and functional details of the flower and its parts.	The teacher will follow the demonstration method to present	

STEPS	MATTER	METHOD	
		TEACHER'S ACTIVITIES	PUPILS' ACTIVITIES
		new matter in the class and will try to elicit as much information as possible from the pupils through suitable questions of heuristic nature.	
		The teacher will distribute flowers in the class and will ask the pupils to observe their shape and colour.	The pupils will observe the flower and recognise its shape and colour.
		The teacher will then demonstrate the method of dissection and will instruct them to dissect the whorls one after another along with him.	The pupils will dissect and draw the various parts systematically.
		The teacher will ask relevant questions in connection with each of the dissected whorls, the answers to which may be possible only through observation and examination of the various parts.	They will also study the shape, colour and the number of constituent members in each of the whorls, through visual and microscopic observation.

Steps	Matter	Method: Teacher's Activities	Method: Pupils' Activities
Generalisation	The points of generalisation may be: (*i*) it is a reproductive organ (*ii*) parts directly connected with reproduction are—androecium and gynoecium (*iii*) importance of the other parts—protection and attraction.	The teacher will generalise the topic with the full co-operation of the pupils. He will ask related questions.	
Application		To test the knowledge acquired, the teacher may resort to either activities or short type questions. *Activities*: (*i*) to prepare lists of common seasonal flowers for summer and winter (*ii*) to prepare lists of scented and scentless flowers (*iii*) to study the	The pupils will try to find out the differences between monocots and dicot; unisexual and bisexual flowers.

Steps	Matter	Method: Teachers' Activities	Method: Pupils' Activities
		parts of a monocot and unisexual flower.	
		Model questions—	
	(1) Crossing for improved strain and selfing for purity of the variety.	(1) What is the importance of flowers in agriculture.	
	(2) Coloured flower parts, wind, insects, etc.	(2) What may be the devices of pollination of the scentless flowers.	
	(3) Jack-fruit tree, fig-tree, etc.	(3) Cite some names of flowering plants, the flowers of which are not easily recognisable.	

Home assignment

Prepare lists of the plants:

(*a*) flowers of which are edible.

(*b*) flowers of which do not bear seeds and fruits.

(*c*) which can be propagated by cuttings.

SPECIMEN LESSON-PLAN 4

School—

Class—VIII

Subject—General Science

Lesson Unit—Formation of rocks and their classification

Average Age—14 years

No. of pupils—

Date—

Time—

Teacher—

General objectives

1. To develop in the pupils the sense of inquisitiveness towards the environment around them.
2. To develop power of observation, scientific thinking and scientific attitude.
3. To develop interest for further study about the structure of the earth we live on.

Specific objectives

(*a*) Knowledge	: To impart knowledge about the information of rocks and their classification.
(*b*) Interest	: To create interest of the pupils in the origin of rock formation.
(*c*) Skill	: To develop the ability to draw diagrams and sketches of different types of rocks.
(*d*) Application	: To enable pupils to recognise different types of rocks and apply their knowledge to identify and classify them.
(*e*) Attitude	: To develop scientific attitude of logical analysis and understanding of the process of rock formation.
(*f*) Appreciation	: To enable the pupils to appreciate the contribution of rocks to human civilisation.

Aids

1. Specimens of different types of rocks.
2. Charts of diagrams of rocks.
3. Wall maps of earth showing various formations on the crust.
4. Magnifying glass and other relevant classroom aids.

Previous knowledge

The pupils have studied the preliminary facts about the earth's crust and different kinds of rocks in general in class VII.

STEPS	MATTER	METHOD: TEACHER'S ACTIVITIES	METHOD: STUDENT'S ACTIVITIES
Preparation	Testing the previous knowledge	On entering the class the teacher arranges the class in order and then asks questions to test their previous knowledge so as to motivate them for the lesson such as—	Pupils will answer the questions
	1. Crust is the upper surface of the earth.	1. What do you understand by crust?	
	2. Some hard materials as sand, rocks, mud, etc.	2. What are the materials that constitute the earth's crust?	
	3. Rock	3. What is the name for the hard matter constituting the crust.	
	Announcement:	After ascertaining the previous knowledge of the pupils, the teacher will announce the day's lesson saying that he will now describe the formation of rocks and their classification. The teacher will write the lesson on the blackboard in bold letters. He will then proceed to present the lesson with the co-	

Steps	Matter	Method	
		Teacher's Activities	Pupil's Activities
		operation of the pupils. He will draw diagrams relevant to the lesson. He will hang charts showing different kinds of rocks and display the specimens or models.	
		The teacher will then ask some questions of the following type (showing the rocks)	Pupils will observe the specimen and answer these questions
	1. Rocks	1. What are these hard materials?	
	2. The hard substances which constitute the crust of the earth.	2. What is a rock? Can you define it?	
	3. Igneous, sedimentary and metamorphic rocks.	3. Can you name the different kinds of rocks?	Pupils observe carefully and feel the rocks with their hands.
		The teacher will then ask the pupils to observe the rocks and then distribute the specimens of different kinds of rocks to the pupils to touch and feel.	
		The teacher will next explain the formation of each kind of rock along	

Steps	Matter	Method	
		Teachers' Activities	Pupil's Activities
		with the accompanying black-board work. To draw their attention and interest he will ask questions like—	
	4. These were formed by cooling of the molten lava.	4. What are igneous rocks? How were these formed?	The pupils will take note of the black-board work, and listen to the questions as answered by the teacher. They also draw necessary diagrams.
	5. Primary rocks.	5. What is the other name for igneous rock? (By the way, the teacher will refer to the eruption of Mt. Visuvious in 79 A.D. and destruction of Pompei in Italy.) He will then ask:	
	6. Volcanic or extrusive rocks.	6. What is the other name for igneous rocks that form the earth's crust?	
	7. Basalt, rhyolite, andesite, etc.	7. Give examples of extrusive igneous rocks.	
	8. Plutonic or instrusive rocks.	8. What is the name for the igneous rocks formed by slow cooling of the magma that remained below the crust?	
	9. Granite,	9. Give examples	

Steps	Matter	Method	
		Teacher's Activities	Pupils' Activities
	diorite, gabbro, etc.	of intrusive igneous rocks. Now, the teacher will proceed to explain the formation of sedimentary and metamorphic rocks with the help of questions like—	
	10. Rocks that are formed by deposit or sedimentation of dust, sand, pebbles, etc., under the lakes or sea beds for centuries. They form in layers and undergo huge pressure, temperature as well as chemical actions.	10. Can anyone tell how sedimentary rocks were formed?	
	11. Stratified rocks	11. What is the other name for sedimentary rocks?	
	12. Sandstone, shale, lime-stone, fossils, etc.	12. Give examples of sedimentary rocks.	
	13. Due to tremendous temperature and pressure under the crust, the	13. What is metamorphic rock? The teacher exhibits specimens of marble, slate, quart-	The students will observe, listen and take necessary notes.

STEPTS	MATTER	METHOD	
		TEACHERS' ACTIVITIES	PUPILS' ACTIVITIES
	igneous and sedimentary rocks undergo changes forming metamorphic rocks.	zite, mica, scist etc.	
Application	14. Marble, slate, mica, scist, gneiss, quartzite, etc.	14. Can you cite some examples of metamorphic rocks?	
		The teacher will then test the pupils' understanding of the topic and their skill of application. He will ask questions of the type—	
		15. What are rocks?	The pupils will try to answer.
		16. Can you point out some application of rocks?	
		17. What is the difference between igneous rocks and sedimentary rocks?	
		18. Classify the following stones into three main types: granite, lime stone, marble, besalt, gneiss, slate, quartzite, pumice, etc.	
		19. What are the causes of metamorphosis of stones?	

Home assignment

1. Draw diagrams of different kinds of stones.
2. Write some points on the use of stones for the growth of our civilisation.
3. Collect pictures of different kinds of stones.
4. Collect some specimens of stones that are found in and around the area where you live.

Appendix

Specimen Objective Tests

(*for higher classes of High and Higher Secondary Schools*)

Q. No. 1

The following statements may be true or false. Put a tick-mark against the relevant answer.

	True	False
(*a*) A constant force produces a constant change in velocity of a body free to move.		
(*b*) In case the above statement is true the change in velocity is dependent upon the initial velocity of the body.		
(*c*) The change in velocity is proportional to the resultant force if the body is acted on by different forces.		
(*d*) Under some circumstances several forces acting on a body from different directions mav produce no change in velocity.		
(*e*) The force acting on a body (moving with a uniform velocity) is dependent upon the velocity.		
( ) A mass can be determined even in absence of the gravitational force.		
(*g*) The mass of a body changes when it is taken out of the earth's gravitational influence.		

Q. No. 2

Find out the foreign-term (term that does not belong to the class) from the following by underlining the term.

(*a*) Force, acceleration, volume, velocity, speed.
(*b*) Mass, density, specific gravity, length, weight.
(*c*) Iron, copper, brass, mercury, platinum.
(*d*) Rubber, paper, leather, glass, cloth.
(*e*) Telescope, microscope, balance, binoculars, stereoscope.
(*f*) Push, pull, acceleration, retardation, germination.

Q. No. 3

Some of the physical events from our day-to-day life are given here. The principles are also mentioned below and are numbered 1, 2, and 3. Write the number of the principle involved against the events.

Events

(*a*) A car moving from rest and driving away . . . (   )
(*b*) A horse pulling a wagon at a constant speed . . .(   )
(*c*) An aeroplane flying at a constant speed . . . . . . (   )
(*d*) A train coming to stop at a station . . . . (   )
(*e*) A stone dropped from the top of a tree . . . . . . (   )
(*f*) A man parachuting down from an aeroplane . . (   )
(*g*) A stone thrown straight up reaches a position when it stops moving up . . . . (   )
(*h*) Brakes applied when the car is moving with a constant speed. . . . . (   )
(*i*) An aeroplane acquiring speed during take off. . .(   )
(*j*) An aeroplane landing at an airport. . . . . (   )

Principles

1. A body moves with a constant velocity when the applied force and the opposing force balance each other.
2. When a force is applied on a body free to move, it will move with accelerated velocity.
3. When a force is applied in the opposite direction on a moving body, it retards the velocity bringing the body to a stop.

Q. No. 4

It is dangerous to step out of a moving bus because when your feet touch the ground they come to rest while the other parts of the body are still in motion; the result is, you will fall flat on the ground.

You can, however, save yourself if you (put a tick-mark against the right answer):

1. jump out facing opposite to the direction of motion.
2. run at the same speed as that of the bus in the same direction.
3. jump out still holding the door of the bus.
4. run at the same speed as that of the bus in the opposite direction.

Q. No. 5

When a certain force is applied for certain time to a mass (M_1) raises the speed by 4 ft/sec. When the same force is applied for the same time on a mass M_2, raises the speed of the body by 12 ft./sec.

This can happen only when (tick-mark the right answer):

(*a*) M_1 is 3 times M_2
(*b*) M_1 is $\frac{1}{3}$ of M_2
(*c*) M_1 is equal to M_2
(*d*) M_1 is 48 times M_2.

Q. No. 6

A standard spring when stressed to an extent of x cms. implies a force Fx. If a body is pulled across a very smooth surface by this standard spring stretched by x cms, the body when released moves with an acceleration 8 cms/sec.^{2} Now, answer the following questions.

(*a*) If the same body is pulled by three standard springs parallel to each other and stretched to the same x cms, then the body will be accelerated by—
A. 8 cms/sec^2., B. 12 cms/sec^2, C. 24 cms/sec^2., D. 48 cms/sec^2.

(*b*) If the same body is pulled by three standard springs joined to one another in series and always kept stretched by x cms, then the body will move with an

acceleration of A. $\frac{8}{3}$ cms/sec^2, B. 8 cms/sec^2, C. 12 cms/sec^2, D. 24 cms/sec^2.

(*c*) The three standard springs are hooked from the same point of the body but pulled in three different directions as follows, always keeping stretched x cms. One spring towards North another towards South and the third towards East. The resultant motion will be one of the following:

A. The body will move towards North with an acceleration 8 cms/sec^2.

B. The body will move towards South with an acceleration 8 cms/sec^2.

C. The body will move towards East with an acceleration 8 cms/sec^2.

D. The body will move towards East with an acceleration 24 cms/sec^2.

Q. No. 7

Two bodies of masses m_1 and m_2 indentical in shape and size, are caused to move across a smooth horizontal surface acted on by the equal forces. It is found that acceleration of m_2 is 1.5 times that of m_1. This is due to one of the following reasons:

A. m_2 is approximately 1.5 times m_1

B. m_1 is approximately .7 times m_2

C. m_1 is 1.5 times m_2

D. m_1 is equal to m_2

Q. No. 8

Two bodies (of same size) m_1 and m_2 are dropped from the top of a house. m_2 is several times heavier than m_1. If the resistance due to air is negligible, you may expect one of the following events:

A. m_2 will reach earth earlier.

B. m_1 will reach earth earlier.

C. Both will reach earth at the same time.

D. Each mass moves with different accelerations.

Q. No. 9

The gravitational pull at the surface of the moon is

approximately one-sixth of that on the surface of the earth. If a boy weighs 120 lbs. on the earth, what will be his weight (approximately) on the moon?

A. 120 lbs.
B. 60 lbs.
C. 20 lbs.
D. 720 lbs.

Q. No. 10

A small wooden cube slides along a frictionless inclined plane. The angle of inclination is 30° with the horizontal surface and the mass of the cube is 200 gms. If the value of *g* is 980 cms/sec^2, what is the force on the body along the inclined plane?

A. 196000 dynes
B. 196000 poundals
C. 98000 dynes
D. 49000 dynes.

Q. No. 11

In Q. No. 10, what is the acceleration of the body along the plane?

A. 1960 cms/sec^2
B. 980 cms/sec^2
C. 490 cms/sec^2
D. 245 cms/sec^2

Q. No. 12

A body of mass *m* gms is thrown vertically upwards with a velocity v cm/sec. If the earth's gravitational attraction is g cm/sec^2, what is the maximum height up to which the body will rise?

A. 2 gv cms.
B. 2 gv^2 cms.
C. v^2/2g cms.
D. 2g/v^2 cms.

Q. No. 13

A stone of mass 250 gms is thrown horizontally from the top of a house h metres high with a horizontal velocity v m/sec. How far away from the house will the

stone drop on the ground? The value of the earth's pull is g gm/sec.

A. 2 hg metres
B. 2 hgv metres
C. $\sqrt{2\ hv/g}$ metres
D. $\frac{v\sqrt{2h}}{g}$ metres

Q. No. 14

The larger raindrops fall more quickly than the smaller raindrops. This can be accounted for as follows:

A. because larger drops are more massive than the smaller one's.
B. it is the property peculiar to the raindrops.
C. air resistance increases as $(radius)^2$ and weight increases as $(radius)^3$, which means that weight increases more rapidly than air resistance.
D. the smaller airdrops accumulate more and more water on the way down till they become sufficiently heavy.

Q. No. 15

The value of earth's pull is g cm/sec. at a place. A rocket with the astronaut in it, accelerates perpendicularly (away from the surface of earth) with an acceleration of g cm/sec. His apparent weight will be:

A. same as that of his weight on the earth.
B. half as that of his weight on the earth.
C. twice as that of his weight on the earth.
D. zero.

Q. No. 16

A motor car travels at different speeds for an interval of time. The following table shows the velocities with which it moves in the different durations of time.

Time interval	Duration of the interval	Speed
1st	T	V
2nd	3T	4V
3rd	T	2V
4th	2T	V/2
5th	T/2	2V

Now answer the following:

(a) What is the total distance of the trip?
(A) 9.5 VT, (B) 7.5 VT, (C) 17 VT, (D) 95 VT.

(b) What is the average speed (per time interval T) for the entire trip?

(c) At the end of the third interval, what is the total distance covered?
A. 17 VT, B. 9.5 VT, C. 15 VT, D. 2 VT.

(d) What is the total time for the whole trip?
A. 9.5 T, B. 7.5 T, C. 1.27 T, D. 1.5 T.

Q. No. 17

A film-projector operates at 16 frames per second. If you want to take movie pictures of a motor car moving at a speed of 60 m/h and to project it to show at half the actual speed (of the motor car), then you will have to take pictures at the rate of (tick-mark the right answer):

(a) 16 frames per sec.
(b) 32 frames per sec.
(c) 8 frames per sec.
(d) 64 frames per sec.

Q. No. 18

A camera automatically takes a photograph after every $^1/_{15}$th of a second. What distance does a bullet, moving at a speed of 3000f/s, travel during the interval between two snaps.

(a) 150 ft.
(b) 300 ft.
(c) 200 ft.
(d) 450 ft.

Q. No. 19

The unit we use to measure inter-stellar distances is (tick-mark the right answer):

(a) mile
(b) kilometre
(c) light-year
(d) hactometer.

Q. N. 20

You can find the height of a tree by observing the length of its shadow. The additional information you need to find the height (tick-mark the appropriate answer) is:

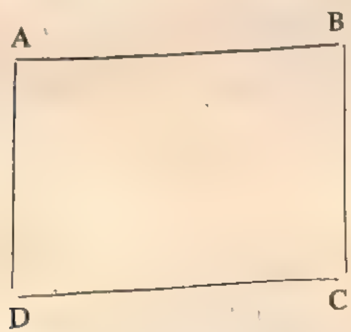
(*a*) The distance from you to the tree.
(*b*) Your own height and the length of your shadow.
(*c*) Distance from the Sun to the tree.
(*d*) Distance from the Sun to your position.

Q. N. 21

A circle of radius 7 cms. is moved along its axis through a distance 10 cms. The volume generated is approximately.

(*a*) 220 cc
(*b*) 1540 cc
(*c*) 15400 cc
(*d*) 50 cc.

Q. N. 22



A B C D is a piece of rectangular cardboard with A B= 10 cms. and B C=5 cms. It is rotated through 180 degrees

about the axis B C. The volume swept out by this motion is approximately (tick-mark the correct solution):

(*a*) 1570 cc
(*b*) 785 cc
(*c*) 39215 cc
(*d*) 3140 cc.

Q. N. 23

A rectangular box has length=l cms, breadth=b cms and height=h cms. If the length, breadth and height are doubled, the total surface area can be represented by (tick-mark the correct answer):

(*a*) 4 (lb+lh+bh)
(*b*) 6 (lb+lh+bh)
(*c*) 8 (lb+lh+bh)
(*d*) 2 (lb+lh+bh).

Q. N. 24

In the above case the new volume will be (tick-mark the right answer):

(*a*) lbh
(*b*) 6 lbh
(*c*) 8 lbh
(*d*) 4 lbh.

Q. N. 25

A cylinder has a base of radius r cms and height of h cms. A second cylinder has a base with twice the radius and twice the length of the first cylinder. How many times is the volume of the second cylinder greater than the first one?

(*a*) 2, (*b*) 4, (*c*) 6, (*d*) 8.

Q. N. 26

A man has to drive a distance of 150 miles. He drives the first 75 miles at 30 miles per hour. How fast must he drive in order to achieve an average of 37.5 miles/hour for the whole journey? (tick-mark the correct answer):

(*a*) 75 mph
(*b*) 50 mph

(*c*) 37.5
(*d*) 60 mph.

Q. N. 27

A boy runs 200 metres in four minutes. What is his speed in km/hour?

(*a*) 6 km/h
(*b*) 3 km/h
(*c*) 9 km/h
(*d*) 1.5 km/h.

Q. N. 28

A car drives past a point at a speed of 30 km/h and a second car drives past the same point after half an hour later at 60 km/h to meet the first car on the way. How long will the second car have to drive to reach the first car? (time counted from the point):

(*a*) 1 hr. (*b*) .5 hr. (*c*) 2 hrs. (*d*) 3 hrs.

Q. N. 29

At time t=0, a car passes at 20 m/s velocity. Another car starts from rest at t=0 and moves with an increasing velocity to reach the car. If the acceleration of the second car is 2 m/s², after what time will the second reach the first car.

(*a*) 2 secs (*b*) 20 secs (*c*) 40 secs (*d*) 10 secs.

Q. N. 30

In a distance time graph (for a car moving at a constant velocity) what does the slope of the straight line graph signifiy?

(*a*) acceleration
(*b*) volocity
(*c*) change of velocity
(*d*) total time

Q. N. 31

A car moves at 50 m/h for 30 minutes, stops for 15 minutes and then moves for 45 minutes at 40 m/h. It stops again for 15 minutes and moves for another 15

minutes at 60 m/h and it reaches its destination. What is the average speed for the whole trip?

(*a*) 35 m/h, (*b*) 65 m/h, (*c*) 32.5 m/h, (*d*) 35.5 m/h.

Q. N. 32

A car increases its speed from 30 m/h to 60 m/h in 10 secs. What is the acceleration of the car?

(*a*) 10 f/s^2, (*b*) 4.4 m/s^2, (*c*) 4.4 f/s^2, (*d*) 110 f/s^2.

Q. N. 33

A car starts from rest with a uniform acceleration. If you draw a speed-time graph, what does the area under the line (graph) indicate?

(*a*) velocity
(*b*) distance
(*c*) acceleration
(*d*) time.

Q. N. 34

A man walks along a circular path of radius 70 feet at a speed of 4.4 f/s. What is his displacement from the starting position after 100 secs.

(*a*) 100 feet
(*b*) 10 feet
(*c*) 7 feet
(*d*) 0 feet.

Q. N. 35

The maximum speed of a boat is 15 m/h in still water. It moves with its maximum speed in a river against the current. What is the net speed of the boat if water flows at 5 m/h?

(*a*) 20 m/h, (*b*) 15 m/h, (*c*) 10 m/h, (*d*) 5 m/h.

Q. N. 36

An aeroplane at a speed of 400 m/h drops food in inaccessible areas. What will be the path of the heavy food bags when dropped from the moving plane?

(*a*) fall straight downward.
(*b*) fall along an inclined straight line.

(*c*) follow a parabolic path till reaching the ground.
(*d*) not fall but move in a straight line parallel to the ground.

Q. N. 37

When a point moves it generates a straight line, when a straight line moves, it generates a surface and when a surface moves it generates a volume. When a volume moves it generates a . . . .? (Fill up the gap)

Q. N. 38

Some of the following statements are true, others are false. If true circle 'T' and if wrong circle 'F'

(*a*) The mass of a body changes with height above the surface of the earth. T F
(*b*) The mass of a body is the same at the centre of the earth as at a height of five miles from the surface of the earth. T F
(*c*) The weight of a body changes with the height from the surface of the earth. T F
(*d*) The weight of a body at the centre of the earth is zero. T F
(*e*) Density of matter varies with height above the surface of the earth. T F
(*f*) Density increases with temperature but decreases with pressure. T F
(*g*) Density decreases with temperature but increases with pressure.
(*h*) Weight of a body depends upon atmospheric pressure. T F
(*i*) Weight of a body increases with the increase in mass of the body. T F
(*j*) Mass of a body depends upon gravity (Earth's pull). T F
(*k*) If the ratio of weights of a body at Guwahati and at Shillong be 1 : .98, then the ratio of the masses of the same body at Guwahati and Shillong will be 1 : .98. T F
(*l*) The apparent loss in weight of a body when immersed in a liquid depends upon

the density of the liquid. T F

(*m*) The apparent loss in weight of a body when immersed in a liquid depends upon the weight of the body. T F

Q. N. 39

(Cancel the incorrect word or words). The actual weight of a body can be determined with the help of a Roman steelyard/ordinary balance/spring balance.

Q. N. 40

One of the following figures expresses Avogadro's number (tick-mark the correct answer).

(*a*) 22.4, (*b*) $6{\cdot}03.10^{23}$, (*c*) $2.5.10^{23}$, (*d*) $1.67.10^{-24}$

Q. N. 41

Each statement to the left is related to one of the names of the scientists mentioned on the right and they are numbered 1, 2, 3, etc. Put the number of the name relevant to the statement in the space provided under brackets.

( ) *a*. At same temperature and pressure, equal volumes of different gases contain the same number of molecules.	1. Robert Boyle
( ) *b*. At constant temperature valume varies inversely as pressure.	2. Galileo Galilei
( ) *c*. Under the action of gravity all bodies fall with equal rapidity.	3. Amadeo Avogadro
( ) *d*. Each action has an equal and opposite reaction.	4. Isaac Newton
( ) *e* When a body is immersed in a liquid it apparently loses some of its weights.	5. John Dalton
( ) *f*. Atom is the smallest particle of an element.	6. Archemedes
( ) *g*. Mass can be converted to energy.	7. Michael Faraday

( ) *h.* If a wire is moved in a magnetic field, current is produced.	8. Albert Einstein
( ) *i.* A planet orbiting around the Sun sweeps out equal area in equal time.	9. Johannes Kepler
( ) *j.* If you swim along the direction of current with your face towards a magnetic needle then the north pole of the needle will be deflected towards your left.	10. Andre Ampere

Q. N. 42

There are some small cubical wooden blocks with sides x inches. This is called B_1 block. B_2 block (cubical) is made with 2 blocks on each side altogether consisting of 8 B_1 blocks. Similarly, B_3 block (cubical) is made with 3 B_1 blocks on each side altogether consisting of 27 B_1 blocks and so on.

A big cubical block B_n is formed with 'n' B_1 blocks on each side. Now tick mark the right answer in reply to the questions to the left.

1. What is the area of the cube B_n?
   (A) $8x^2n^2$
   (B) $6x^3n^3$
   (C) $36x^2n^2$
   (D) $6x^2n^2$

1. What is the volume of the cube B_n?
   (A) $3x^3n$
   (B) x^3n
   (C) x^3n^3
   (D) xn^3

2. How many small B_1 cubes are there in cube B_n?
   (A) n^2
   (B) n^3
   (C) n^4
   (D) n

Q. N. 43

Underline the term which does not belong to the group.

1. Cube, sphere. volume, cone, cylinder.
2. Cork, paper, rubber, wood, copper.
3. Kilometre, mile, yard, gram, micron.
4. Density, specific gravity. mass, specific heat weight.

Q. N. 44

There are many objects which can be classified into the following four types. Each type consists of objects of the following specifications.

	Volume	*Density*
Object A	4 cc	2 gm/cc
Object B	3 cc	2 gm/cc
Object C	2 cc	1 gm/cc
Object D	1 cc	1 gm/cc

Now, answer the following questions and tick-mark the right answer:

If you compare the objects with the help of an arm-balance then.

1. Object A will be balanced by:
   A. object B and object C
   B. object B and object D
   C. object D and object C
2. Object B will be balanced by: —
   A. object A and object D
   B. object C and object D
   C. object A and object C
   D. 3 objects C
3. (object B + object D) will be balanced by:
   A. 2 objects C + 2 objects D
   B. 2 objects C + object D
   C. object A + 2 objects D
   D. 3 objects C + object D
4. (object B + object C) will be balanced by:
   A. 3 objects D + object A
   B. 2 objects C + object D
   C. object A + object D
   D. object A

Q. N. 45

Under certain conditions 23 gms of an element X react with 35 gms of element Y to form 58 gms of compound Z.

1. Under the same conditions if 10 gms of X react with 17.5 gms of Y then the result may be one of the following:
   A. (Approximately) 27.2 gms of compound Z.
   B. 25.2 gms of compound Z and 2.3 gms of Y.
   C. 29 gms of compound Z.
   D. 17.5 gms of compound Z.

Q. N. 46

Under the same conditions, if 49 gms of element X react with 70 gms of element Y, then the result may be one of the following:

A. 70 gms of compound Z and 49 gms of X.
B. 119 gms of compound Z.
C. 116 gms of compound Z and 3 gms of X.
D. 116 gms of compound Z and 3 gms of Y.

Q. N. 47

An egg sinks in water but floats in salt solution. This can be due to one of the following reasons.

A. The egg has a hard shell.
B. Water exerts downward pressure.
C. Salt solution has higher specific gravity than the egg.
D. Salt solution has higher specific gravity than water.

Q. N. 48

Three boys, P, Q, and R stand in a line. The distance between P and Q and between Q and R is the same and is equal to X ft. P stands still; Q and R revolve round P in a circular path with the same angular velocity W. Answer the following questions.

1. What is the ratio of the velocities of Q to that of R?
   A. 1:4
   B. 1:2

C. 2:1

D. 1:1

2. What is the ratio of frequencies of rotation of Q to that of R?

A. 1:2

B. 2:1

C. 1:1

D. 4:1

3. What is the value of frequency of rotation of R?

A. $2 \pi W$

B. $\frac{2\pi}{W}$

C, $\frac{W}{2\pi}$

D. $2 \pi + W$

4. What is the velocity of the boy R around the boy P?

A. $2 \pi X$

B. $2 \pi X W$

C. $2 X W$

D. $\frac{2 \pi X}{W}$

5. What is the time-period of revolution of Q?

A. $2 \pi W$

B. $\frac{2 \pi}{W}$

C. $W/2\pi$

D. $2 \pi X W$

6. What is the ratio of the time period of Q to that of R?

A. 2:1

B. 1:2

C. 1:1

D. 2M:W

7. The distance between P and R is doubled. What will be the ratio of the present velocity of R to its original velocity of R still keeps in the same ratial line as before?

A. 1:2

B. 1:4

C. 4:1

D. 2:1

8. In the above case, what is the value of the new linear velocity of R?
   - A. $2\pi W$
   - B. $2XW$
   - C. $4XW$
   - D. $4\pi W$
9. What is the ratio of the present velocity of R to that of Q, the angular velocity being the same?
   - A. 1:4
   - B. 4:1
   - C. 2:1
   - D. 1:2
10. If Q and R exchange their positions then one of the following may happen.
    - A. Their frequencies will change.
    - B. Their angular velocities will be different.
    - C. Ratio of their linear velocities will remain the same.
    - D. Ratio of their linear velocities will be reverse.

Q. N. 49

In this exercise a few rules A, B, C and D are given. Below the rules are given some statements. You are to recognise whether the statements illustrate any of the rules mentioned or not. If it is an illustration of rule A, circle A, if it is an illustration of B circle B and so on. If it is not an illustration of any of the rules, circle X.

Rules

- A. Metals expand when heated.
- B. Some substances are better absorbers of heat than others.
- C. Heat travels by radiation, conduction and convection.
- D. Some substances are better conductors of heat than others.

Statements :

1. When fitting an iron ring around the wooden wheel of a bullock-cart, it is first heated to redness and then placed around the wheel.

When it cools it gets tightly fitted to it. ABCDX

2. Two rods, one of iron and the other of wood, were heated together at one end. A small boy touched the other ends one after another. He cried in pain when he touched the iron rod. ABCDX
3. In the winter you bask in the Sun to warm up. ABCDX
4. In winter people wear woolen clothes in place of cotton clothes to keep themselves warm. ABCDX
5. A drum full of water is heated from below. After some time it is found that all the water in the drum became warm as you could feel by placing your hand on the surface of water. ABCDX
6. There are small gaps at the joints of the railway lines. ABCDX
7. When three identical balls heated to the same temperature are placed on a tray of wax, they penetrate to different distances through the wax. ABCDX
8. Water-bag is made of rubber. ABCDX
9. Liquids in a thermos-flask remain hot for a long time. ABCDX
10. In summer concrete buildings are comparatively cooler at noon when the Sun is strongest and warmer in the evening when the Sun's rays are not very hot. ABCDX
11. If the metallic wire-net in "Davy's safety lamp" is replaced by a perforated mica-sheet, it is no longer a safety lamp. ABCDX

Q. N. 50

Given below are some facts and the possible reasons for them. But some of them are real reasons and some of them are not. Circle "Yes" if it is a reason and "No" if it is not.

Facts

A. We use mercury in a thermometer.

Possible reasons: Because:		
1. It can be used through a wide range.	Yes	No
2. It is very heavy.	Yes	No
3. It is a good conductor of heat and electricity.	Yes	No
4. It does not stick to the glass.	Yes	No
5. It expands uniformly.	Yes	No
6. Quickly transmits and distributes the heat.	Yes	No
7. It does not have any smell.	Yes	No
8. It has no colour.	Yes	No
9. It is a shining, opaque liquid.	Yes	No
10. It is a metal.	Yes	No
11. It can readily be obtained pure.	Yes	No
12. Even iron floats on it.	Yes	No

Q. N. 51

Facts

B. A spring balance is used to get the true weight of an object (ordinary balance compares masses only).

Reasons: Because:		
1. The spring is made of steel.	Yes	No
2. The weight of a substance varies with altitude and latitude and the spring balance shows the variation in weight.	Yes	No
3. It measures the actual force of the earth acting upon the substance.	Yes	No
4. It is portable.	Yes	No
5. Once calibrated, it does not need any additional modification to find the weight of a substance.	Yes	No

Q. N. 52

C. For sealing metallic wires into glass, platinum is always chosen.

Because:		
1. Glass and platinum are so easily available.	Yes	No
2. Platinum is very valuable.	Yes	No
3. Platinum is a good conductor of heat.	Yes	No
4. Co-efficient of expansion of heat of both glass and platinum are almost the same.	Yes	No
5. Glass does not crack on cooling.	Yes	No

Q. N. 53

D. *Facts*:

Once we charge the electrophorus, we can get any amount of electricity.

Reasons: Because:

1. Infinite amount of electric charge is deposited there. Yes No
2. The electrophorus gets charge from the earth. Yes No
3. In the electrophorus mechanical energy spent in doing work by drawing it is converted into electrical energy. Yes No

Q. N. 54

E. *Fact*:

The water reservoir of the town water-supply system is generally on the highest place of the town.

Reasons:

1. Because water remains pure at high attitude. Yes No
2. Because the pressure may be sufficient to supply water to all parts of the town. Yes No
3. Because water remains cold there. Yes No
4. Because it is convenient to use iron pipes from there. Yes No
5. Because rain water may flow into the water in the reservoir. Yes No

Q. N. 55

A. Here some statements to be classified according to the kind (stated on the right) to which they belong. Simply put a tick mark under the appropriate kind.

Classification with respect to laws of motion

Statement:	1st law	2nd law	3rd law
(*a*) When you fire a gun, the forward motion of the bullet gives a backward push to the gun.	—	—	—

	1st law	2nd Law	3rd law
(*b*) When the city bus suddenly stops, all the passengers inside experience a forward thrust.	—	—	—
(*c*) While playing marbles, the two marbles (striker and the one struck) move in different directions.	—	—	—
(*d*) When you are the batsman, how far the cricket ball rolls will depend on how strong you are.	—	—	—
(*e*) When you are walking, what law do you think is being exercised?	—	—	—
(*f*) While running a race you cannot suddenly stop just on the line marking the end point.	—	—	—

Q. N. 56

B. Classification with respect to energy.

Statement:	*E.K.*	*P.E.*
1. Stone you throw with force.	—	—
2. The water in the water tank on the roof of a building.	—	—
	—	—
3. The bullet when fired.	—	—
4. The spring of the watch fully wound.	—	—
5. Wind blowing with velocity.	—	—
6. The river flowing down a mountain.	—	—
7. A moving train.	—	—
8. The books on the table.	—	—
9. The fruit hanging on the tree.		
10. The cricket ball when struck with the bat.	—	—

Q. N. 57

C. Classification with respect to equillibrium.

Statement	*Stable*	*Unstable*	*Neutral*
1. A man standing on one leg.	—	—	—
2. A ball lying on the ground	—	—	—
3. A table resting on four legs.	—	—	—
4. A man on a bicycle when not moving.	—	—	—
5. A bottle resting upside down on the mouth.	—	—	—
6. A cone resting on the side.	—	—	—
7. A heavily loaded ship.	—	—	—
8. A chair on two legs.	—	—	—

Q. N. 58

D. Classification with respect to type of lever.

	Kind of lever		
	1st	2nd	3rd
1. A common balance	—	—	—
2. A sea-saw	—	—	—
3. A pair of scissors	—	—	—
4. Handle of a hand pump	—	—	—
5. Human arm	—	—	—
6. Brake of a motor car	—	—	—
7. The typewriter keys	—	—	—
8. A nail cutter	—	—	—

Q.N. 59

Given below are some examples of energy transformation. The answers are also given. You are to circle the appropriate type or types of energy transformations that have occurred.

Types:

A. Mechanical to electrical.
B. Potential to kinetic.
C. Electrical to heat.
D. Electrical to light.
E. Sound to electrical.
F. Electrical to sound.

G. Mechanical to sound.
H. Potential to electrical.
I. Chemical to electrical.
J. Electrical to mechanical.
K. Heat to mechanical.

Examples

1.	Hydro-electricity.	A B C D E F G H I J K
2.	The electric iron.	A B C D E F G H I J K
3.	The bulb when burning.	A B C D E F G H I J K
4.	A mango when detached from a branch falls with velocity and makes a sound on the ground.	A B C D E F G H I J K
5.	The microphone when working.	A B C D E F G H I J K
6.	The grammophone when played.	A B C D E F G H I J K
7.	The tuning fork gives sound when struck.	A B C D E F G H I J K
8.	The catapult when pulled.	A B C D E F G H I J K
9.	The cell giving us current.	A B C D E F G H I J K
10.	During lightning.	A B C D E F G H I J K
11.	Water wheel.	A B C D E F G H I J K
12.	The dynamo.	A B C D E F G H I J K
13.	The motor.	A B C D E F G H I J K
14.	The tram car.	A B C D E F G H I J K
15.	The steam engine.	A B C D E F G H I J K
16.	When you get electricity from an electrophorus.	A B C D E F G H I J K
17.	The wind-mill.	A B C D E F G H I J K
18.	The electric fan when running.	A B C D E F G H I J K
19.	The electric bell.	A B C D E F G H I J K
20.	The sound of thunder.	A B C D E F G H I J K

Q. N. 60

A. Here some statements where gaps are provided to complete with appropriate words from given on the right hand side.

For example

The metal that is used for electric light is (tungsten)	(copper, tungsten, silver, steel.)

Now answer

1.	Mercury is a ( ) metal.	(solid, liquid, gas)
2.	Water vapour is ( ) than air.	(heavier, lighter).
3,	Velocity of a body falling from rest is proportional to the ( )	(time, distance, weight of the body)
4.	Space traversed by a body freely from rest is proportional to the ( )	(square of time, weight of the body, cube of time)
5.	Mass is the quantity of matter in unit ( )	(length, volume, time)
6.	Doctors use ( ) thermometer.	(Centigrade, Fahrenheit Reaumur)
7.	Boiling point of a substance varies with ( )	(temperature pressure, quantity of substance)
8.	A barometer measures the ( ) of the atmosphere.	(temperature, pressure, weather).

Q. N. 61

Fill up the gap in the following statements with proper words.

1. A lactometer reads..............mark when immersed in water.
2. At sea-level atmospheric pressure is equal to .... cms. of mercury.
3. Mass is the .... of matter in the body.
4. Every material particle .... every other particles.
5. Attraction between the .... of different matters is called force of ....
6. Attraction between the .... of the same matter is called force of ......
7. Force with which earth attracts all the bodies is called ....
8. In a closed vessel filled with a gas, the pressure inside ....as the temperature rises.

9. The amount of heat required to raise the temperature of one gram of water through one degree is called a ....
10. The quantity of heat required to raise the temperature of any body through one degree is called ....
11. Exchange of heat between two bodies depends upon the .... of temperature between them.

Q. No. 62

Given below are statements some of which are true and others false. Circle 'T' if it is true and 'F' if it is false.

Sample: No heat is necessary to prepare a mechanical mixture.	(T)	F
1. Least count is the smallest amount which the instrument can measure.	T	F
2. To pull an object is easier than pushing.	T	F
3. A stone tied with a thread and revolved around will have a tendency to fly outwards.	T	F
4. Force due to gravity decreases as we go towards the centre of the earth.	T	F
5 Force due to gravity increases as we go up above the ground.	T	F
6. Sound travels through vacuum.	T	F
7. Without friction, walking would have been impossible.	T	F
8. A perfect machine is impossible.	T	F
9. There is high temperature and low pressure inside the earth.	T	F
10. Mechanical advantage of a system of pulleys depends upon the number of pulleys.	T	F
11. When two balls, one of iron and the other of wood, are dropped from a great height they will reach the ground almost simultaneously.	T	F
12. Time-period of a pendulum depends upon the mass of the bob.	T	F

13. Apparent expansion = real expansion plus expansion of the glass vessel. T F
14. It is not possible to produce complete vacuum with the help of an exhaust pump. T F
15. Time period of a pendulum varies directly as the square root of its length. T F
16. Work = Power × Time. T F
17. Flattening of the earth at the poles has been caused by the revolution of the earth around its axis. T F
18. Absolute motion cannot be realised in nature. T F
19. Velocity is the rate of change of position in a given direction. T F
20. Water finds its own level. T F

Q. No. 63

In column 'X' statements are made about some scientific laws or processes and in column 'Y' the names of those laws or processes are given and numbered 1, 2, 3, etc. Insert the number of the law in the bracket against the statement to which the law pertains.

( ) (*a*) When two sounds of the same type and intensity and of nearly the same frequency of vibration are produced together, a fluctuation of loudness occurs due to the interference of the two notes.	1. Evaporation
( ) (*b*) When a body is forced to vibrate, if the period of the applied force is the same as that of the body, then it vibrates with much greater amplitude than when the periods are not the same.	2. Boyle's law
( ) (*c*) The change of a substance from liquid to vapour state takes place at all temperatures.	3. latent heat

( ) (*d*) There are cases where a solid undergoes liquification on fusion absorbing heat without any rise in temperature.	4. Newton's First Law
( ) (*e*) When temperature remains constant, the pressure of a gas varies inversely as the volume.	5. Resonance
( ) (*f*) Total amount of matter in the universe remain constant.	6. Pascal's Law
( ) (*g*) To every action is always an equal and opposite reaction.	7. Newton's Third Law
( ) (*h*) Pressure applied anywhere in a liquid is transmitted equally in all directions.	8. Law of conservation of masses
( ) (*i*) A body immersed in a fluid experiences an upward thrust.	9. Buoyancy
( ) (*j*) Every body continues in its state of rest or of uniform motion in a straight line, unless disturbed by some external force to change that state.	10. Siphon principle
( ) (*k*) If there are two containers of water at different levels and they are connected by a Pipe already filled with water, the water from the container at the higher level will be transfered to the lower one.	11. Beats

Q. No. 64

The descriptions of some instruments are given below and the names of the instruments are also given on the right. You are to pick the name of the instrument and match it against the description in the space provided (in brackets)

1. An instrument used for reception of sound under water and also to finding out the direction of sound. ( )	1. Thermopile
2. A very sensitive electrical instrument to measure temperature ( )	2. Manometer
3. An oil lamp which may be used safely in underground mines ( )	3. Hygrometer
4. An instrument used to determine the state of dryness or wetness of air at any place ( )	4. Davy's safety lamp.
5. An instrument used for measuring pressure of a gas ( )	5. Hydrophone
6. An apparatus for measuring the pressure of the atmosphere ( )	6. Stable equilibrium.
7. A body at rest if slightly displaced tends to return to its original position. ( )	7. Capillarity
8. The oil passes through the wick and keeps the lamp burning in an oil lamp ( )	8. Spherometer
9. An instrument generally used for determining the radius of curvature of spherical surface. ( )	9. Pump
10. An instrument with which air can be forced into ( )	10. Barometer
11. When a body is immersed in a liquid, it loses a part of its weight equal to the weight of the volume of liquid displaced by the body. ( )	11. Hook's law
12. Within the elastic limit a metal string expands proportionately to the force applied. ( )	12. Principle of Archimedes

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Arun K. Gupta

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Dr Arun Gupta is Director, Model Institute of Education and Research, Jammu.

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কর্ডি টেনডিনি (Chordae tendinae) নামক সুতার ন্যায় অসংখ্য পেশীর উপরে অলিন্দ-নিলয় কপাটক অবস্থান করে।

কোনাস আর্টারিওসাস (Conus arteriosus) ঃ কুনো ব্যাঙের দক্ষিণ অলিন্দের অঙ্কদেশে নিলয়ের ডানদিক থেকে নলাকার কোনাস আর্টারিওসাস উত্থিত হয়। নিলয় ও কোনাস আর্টারিওসাসের সংযোগস্থলে তিনটি **অর্ধচন্দ্রাকার কপাটক** (Semilunar valve) বর্তমান। কোনাসের গহবরটিও একটি অনুদৈর্ঘ্যে বিন্যস্ত **সর্পিল কপাটক** (Spiral valve) দ্বারা নিয়ন্ত্রিত ও দুটি ভাগে বিভক্ত হয়। দক্ষিণ দিকের অংশটি **কেভাম অ্যাওর্টিকাম** (Cavum aorticum) এবং বাম দিকের অংশটি **কেভাম পালমোকিউটেনিয়াম** (Cavum pulmocutaneum) নামে পরিচিত।

নিলয় থেকে উত্থিত কোনাস আর্টারিওসাস-এর অগ্রবর্তী অংশ **ট্রাঙ্কাস আর্টারিওসাস** (Truncus arteriosus)-এ বিভক্ত হয়। ট্রাঙ্কাস হৃৎপিণ্ডের অংশ নয়। তবে ট্রাঙ্কাস থেকেই **ক্যারটিড খিলান ধমনীগুলি** (Carotid arches) উত্থিত হয়।

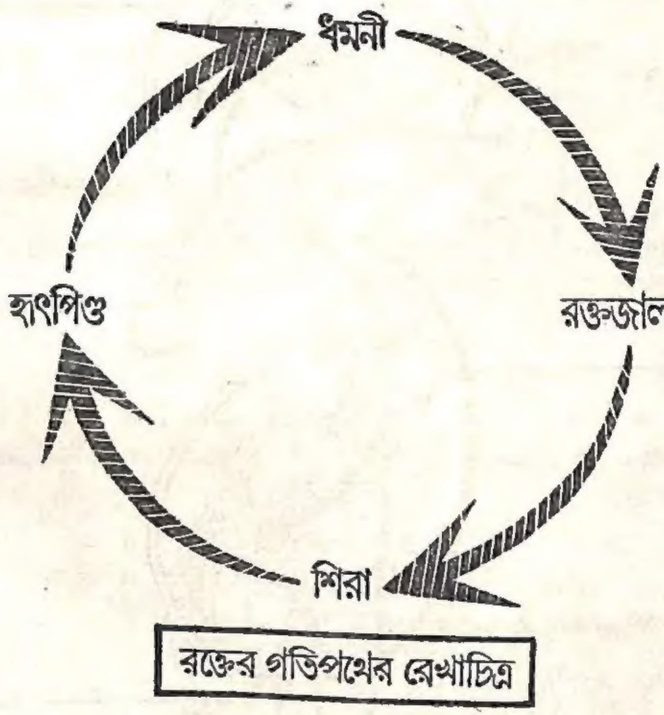
17.5. কুনো ব্যাঙের হৃৎপিণ্ডের মধ্যে দিয়ে রক্তের চক্রাবর্তন *[Mechanism of circulation of blood through the heart of Toad] :*

কুনো ব্যাঙের হৃৎপিণ্ডে **দ্বিচক্রী** (Double circuit) প্রথা অনুসৃত হয়। এদের একটি **সিস্টেমিক চক্র** (Systemic circuit) এবং অন্যটি **ফুসফুসীয় চক্র** (Pulmonary circuit)। সিস্টেমিক চক্র মাধ্যমে হৃৎপিণ্ড দেহের প্রতিটি অঙ্গে বিশুদ্ধ রক্ত সরবরাহ করে এবং অশুদ্ধ রক্ত ফিরিয়ে আনে। ফুসফুসীয় চক্র মাধ্যমে হৃৎপিণ্ড থেকে রক্ত ফুসফুসে যায় এবং সেখানে পরিশ্রুত হবার পরে রক্ত পুনর্বার হৃৎপিণ্ডে ফিরে আসে।

জীবিতাবস্থায় হৃৎপিণ্ড সর্বক্ষণ পর্যায়ক্রমে সঙ্কুচিত ও প্রসারিত হ'য়ে উভয় চক্র মাধ্যমে রক্তের সুষ্ঠু চক্রাবর্তনে সহায়তা করে। হৃৎপিণ্ডের এই সঙ্কোচন

ও প্রসারণকে যথাক্রমে **সিস্টোল** (Systole) এবং **ডায়াস্টোল** (Diastole) বলে।

হৃৎপিণ্ডের প্রসারিত অবস্থায় অক্সিজেনবিহীন অপরিস্রুত রক্ত দু'টি **প্রি-কেভাল** (Pre-caval) এবং একটি **পোস্ট-কেভাল** (Post-caval) শিরার মাধ্যমে হৃৎপিণ্ডের সাইনাস ভেনোসাসে ফিরে আসে। ইতিমধ্যে সাইনাস ভেনোসাস সংকুচিত হ'লে সেখানে সঞ্চিত অপরিস্রুত রক্ত সাইনু-অরিকুলার ছিদ্রপথে দক্ষিণ অলিন্দে পৌঁছায়। দক্ষিণ অলিন্দের প্রাকার ভাঁজ হ'য়ে বাধার



চিত্র 17·9—হৃৎপিণ্ডের মাধ্যমে রক্তের চক্রাবর্তন।

সৃষ্টি করার ফলে দক্ষিণ অলিন্দে অনুপ্রবিষ্ট রক্ত পুনরায় সাইনাস ভেনোসাসে ফিরে যেতে পারে না। সর্বাঙ্গ থেকে সারা দেহের রক্ত যখন সাইনাস ভেনোসাস মাধ্যমে দক্ষিণ অলিন্দে আসে, সেই একই সময়ে ফুসফুস থেকে পরিস্রুত রক্ত ফুসফুসীর শিরা মাধ্যমে বাম অলিন্দে পৌঁছায়।

অলিন্দদ্বয় রক্তপূর্ণ হওয়া মাত্র, একই সঙ্গে সংকুচিত (সিস্টোল) হয়, এদিকে ঐসময় নিলয়ের প্রসারণ বা ডায়াস্টোল দশা চলে। ফলে দক্ষিণ অলিন্দ থেকে অপরিস্রুত রক্ত এবং বাম অলিন্দ থেকে পরিস্রুত রক্ত অলিন্দ-নিলয় ছিদ্রপথ মাধ্যমে নিলয়ে নেমে আসে। দক্ষিণ অলিন্দ ও বাম অলিন্দের মাঝখানে